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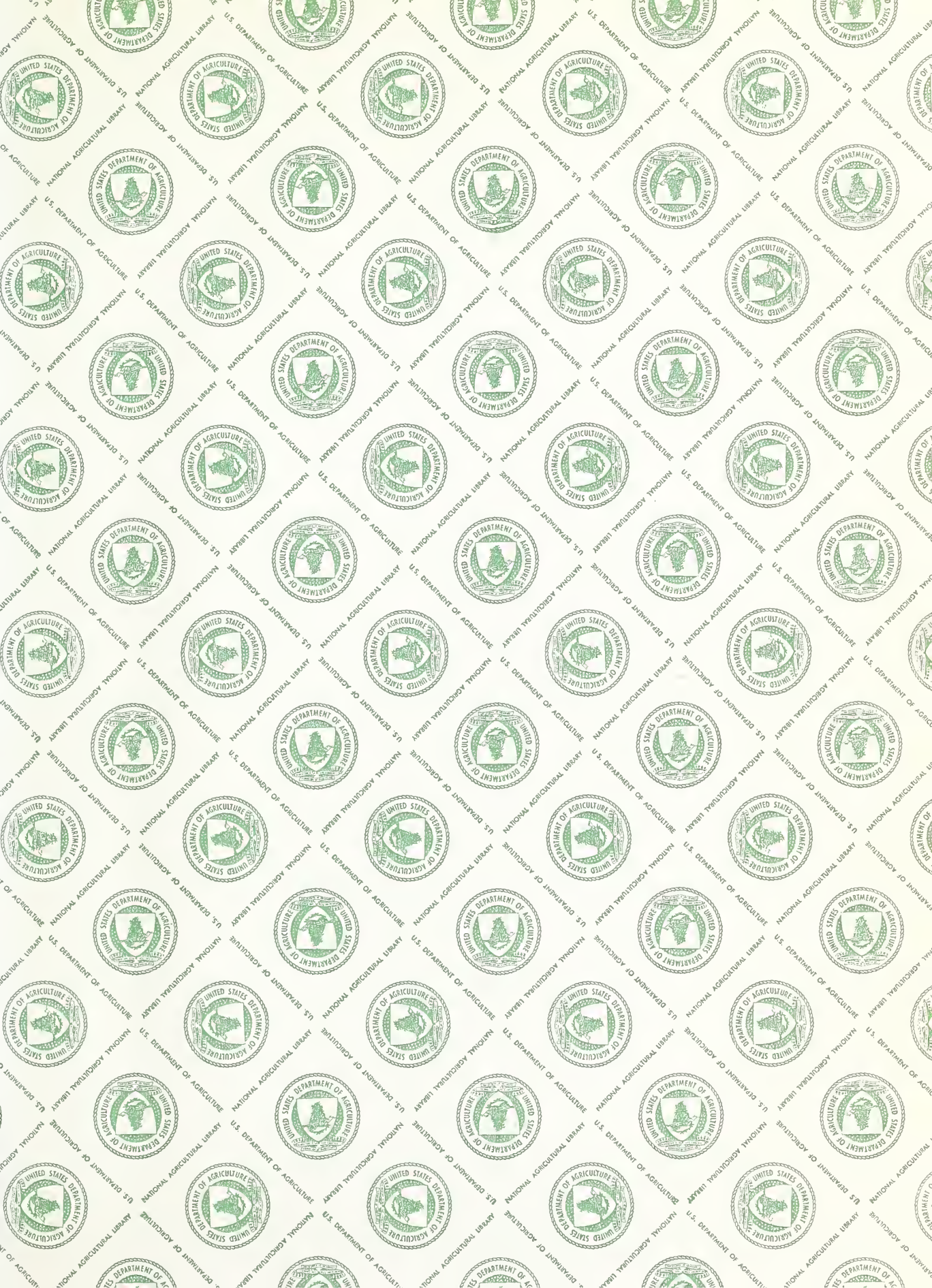
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A Summary of Current Program 7/1/66

and Preliminary Report of Progress

for 7/1/65 to 6/30/66

ENTOMOLOGY RESEARCH DIVISION

of the

AGRICULTURAL RESEARCH SERVICE

UNITED STATES DEPARTMENT OF AGRICULTURE

and related work of the

STATE AGRICULTURAL EXPERIMENT STATIONS

Section A

This progress report is primarily a tool for use of scientists and administrators in program coordination, development, and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

The summaries of progress on USDA and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed, will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members, and others having a special interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of USDA and cooperative research issued between July 1, 1965, and June 30, 1966. Current agricultural research findings are also published in the monthly USDA publication, Agricultural Research. This progress report was compiled in the Entomology Research Division, Agricultural Research Service, U.S. Department of Agriculture, Beltsville, Md.

UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C.

July 1, 1966

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INTRODUCTION

Entomology research is concerned with both destructive and beneficial insects in relation to the growing of fruits, vegetables, forage, grain, cotton, tobacco, sugarcane, sugarbeets, and ornamental crops; turf, pasture and range plants; the management of bees in relation to pollination and honey production; and the production of all classes of livestock and poultry. In addition, it includes investigations on insects affecting man, households, and industrial establishments; the identification and classification of insects; the biological control of weeds; and on chemicals including insecticide residues on all raw agricultural commodities derived from crops and livestock.

Insects (including ticks and mites) constitute the largest class of animals. Approximately 85,000 kinds occur in the United States, of which 10,000 are regarded to be of economic significance. Insects are both destructive and useful. They are man's greatest competitor for food and fiber, and at the same time they are vital to man's existence. Without honey bees and other insect pollinators, many important crops could not be grown, and without the insect parasites and predators, which help to maintain a reasonable balance between harmful and beneficial species, destructive insects would increase to such numbers that it would almost be impossible to control many of them even with our best control measures.

All crops in every stage of growth are subject to attack by insects. Seeds placed in the ground may be destroyed before or during sprouting. Growing plants have their roots, stems, leaves, or fruit damaged by many kinds of chewing and sucking insects. Livestock are infested by numerous insects, ticks, and mites. Insects are important in that they cause annoyance and losses due to direct feeding and also because they are responsible for the spread of many of the most serious diseases affecting plants, animals, and man. Thus, it is understandable why insects exact a toll of the Nation's resources estimated at almost 7 billion dollars annually.

Outstanding progress has been made in the development of control methods for most of the major insect pests, by developing chemical, cultural, biological, and genetic control procedures. Of these various procedures, chemical control methods are now employed to meet about 90 percent of our insect problems. However, the use of insecticides has led to many problems that are of growing concern to the public, such as residues in foods, and adverse effects to fish and wildlife, beneficial insects, and other organisms in the treated environment. Because of such problems major shifts in emphasis have been made in the entomology research program to strengthen research on biological control methods, the development of plant varieties resistant to insect attack, attractants and baits to provide specific methods of control for certain insects, and the exploration of other new approaches such as the use of sterile insects for their own destruction. All of these methods offer excellent possibilities for improving insect control and eradication procedures.

The Entomology Research Division has work located at 6 field locations in the United States, 7 locations in foreign countries, and one in the Virgin Islands. The Division and the Branch leadership staffs responsible for the administration of research programs throughout the country and abroad are headquartered at Beltsville, Md. Two Pioneering Laboratories, one on Insect Pathology and the other on Insect Physiology, both devoted to basic research, are also located at Beltsville. In addition, basic research is conducted by entomologists and chemists at Beltsville, in cooperation with scientists of other disciplines. Insect identification research is conducted in Washington in close collaboration with the Smithsonian Institution.

The personnel at field locations cooperate closely with State Experiment Station and university scientists. There is also close cooperation with trade associations, industrial establishments, health agencies, and growers. Most of the applied research is conducted at the field locations and such research will continue; however, more and more attention is being given to basic investigations pointing to better long-range solutions to insect problems of national significance.

Cooperation is also maintained with other research divisions in the Agricultural Research Service and with divisions of the Service concerned with plant and animal pest-control and plant and animal quarantine programs. There is also cooperation with other research and regulatory divisions in the Department of Agriculture and with other agencies including the Departments of Defense, State, Interior, and Health, Education and Welfare, Atomic Energy Commission, World Health Organization, and the International Atomic Energy Agency.

The Division also sponsors 125 domestic research projects through grants, contracts, and cooperative agreements negotiated with State experiment stations, universities, boards of health, and independent laboratores throughout the United States.

The Division also sponsors 68 research projects in 14 foreign countries financed under the Public Law 480 program for utilizing foreign currencies received in payment for excess agricultural products from the United States. Research is conducted under agreements with the Agency for International Development in Nigeria, Uganda, and Rhodesia in Africa, and Karaj, Iran.

A broad analysis of the Division's research by different approaches to insect control shows that about 20 percent of the current effort is on the conventional chemical approach to insect control; 12 percent on biological control (parasites, predators, and pathogens); 7 percent on plant resistance to insects; 26 percent on the sterility and other new approaches to insect control such as natural attractants; and 35 percent on other entomology research including basic biology, physiology, taxonomy, apiculture, and insect vectors of diseases. Substantial changes in the research effort have been made in the last 8 years to place more emphasis on nonchemical or on special chemical approaches to insect control.

A few examples of recent outstanding developments indicating the continuing value of basic and applied entomological research to the Nation's agriculture and general welfare follow:

ENTOMOLOGY RESEARCH DIVISION, ARS

Pink bollworm sex attractant isolated and synthesized. The sex pheromone has been isolated in pure form from the female pink bollworm, its chemical structure shown to be 10-propyl-trans-5,9-tridecadienyl acetate (named propylure), and it has been synthesized in the laboratory. The pure synthetic material is highly attractive and stimulatory to adult male moths in the laboratory. High concentrations of either purified natural lure or synthetic propylure were found to be necessary to lure males into field traps. When an inactive extract of female moths is added to either the natural or synthetic propylure the mixture is as active as crude natural lure in attracting male moths to field traps. The chemical nature of this activator is being investigated.

Method for detection of chemosterilants developed. Gas-liquid chromatographic procedures have been developed for the analysis of the chemosterilants tepa, metepa, methiotepa, hempa, and apholate. The method employs a flame photometric detector and is sensitive to about 0.1 nanogram. When the procedure was used to recover tepa from adult fall armyworms, no interference was encountered. The ability to detect these chemosterilants in such small amounts enables the working out of conditions under which large scale field tests may be conducted safely.

Sterility methods of control of codling moth. Experimental sterile male releases were used instead of insecticides to control the codling moth in approximately 17 acres of apple orchard in Washington. An overflooding ratio as high as 400 sterile moths to 1 wild moth was achieved. Worm entries were comparatively rare in the release orchard. With the reduced amounts of insecticide employed in the orchard, marked improvement in the effectiveness of biological control of other pests was noted.

Electrical-mechanical control of horn flies. Horn flies on dairy cattle were effectively controlled with an electrochemical device which avoids the risk of contamination of cattle, milk, and milking equipment. BLB fluorescent lamps are installed in box-like containers and insecticide impregnated gauze protected by hardware cloth placed in front of the lamps. When units are installed on both sides of entrances, horn flies are attracted to the lights, contact the treated gauze and die in a few minutes. When operated in total or semidarkness, these devices reduced large horn fly populations by 90 to 95% within 7 to 10 days and maintained effective control thereafter. Studies are underway to create a semidark environment at entrances to barns to render the units effective at all hours.

Reflective aluminum repels aphids and reduces incidence of aphid-borne virus diseases on vegetables and ornamentals. Insecticides frequently fail to kill insect vectors of plant diseases quickly enough to prevent transmission

of the disease organisms. Research, which has been underway since 1963, has demonstrated significant reductions in the incidence of cucumber mosaic, squash mosaic, watermelon mosaic and gladiolus viruses by repelling aphids with aluminum mulches. In 1965 aluminum foil mulches repelled aphids, banded cucumber beetles, and Mexican bean beetles from squash and beans. Flying aphids were reduced 93% in squash planting with aluminum mulch and only 4% of the mulched plants were infected with aphid-transmitted viruses, compared to infection of 69% of the check plants. Yield was increased six-fold in the aluminum plots. Research is being continued to characterize the repellancy properties of reflective aluminum.

Ecological control of green peach aphid to protect sugarbeets from virus disease. Studies showed that drainage ditches in Washington provide protection during the winter for summer forms of the green peach aphid and their weed hosts, many of which are sources of beet western yellows virus. Destruction for the second year of weeds along irrigation and drainage ditches and canals by burning resulted in 74% fewer beets in the test area with symptoms of the disease which is transmitted by these aphids.

Biological control of pea aphids on alfalfa to protect peas from virus disease. Approximately 100 million parasitic wasps (Aphidius pulcher Baker) were reared on pea aphids infesting alfalfa inside heated plastic covered field cages early in the spring in Washington. Released parasites invaded about 15,000 acres of alfalfa, overflooding the native aphid population and delayed migration of aphids to pea fields where they are vectors of pea enation virus.

An integrated control program reduced the number of insecticide applications required to control shade tobacco insects by 76%. Light traps were used in combination with a soil treatment of a systemic insecticide, and foliage treatments with Bacillus thuringiensis and nonpersistent pesticides.

Hylemya seneciella to control tansy ragwort. The larvae of a seed-head fly, Hylemya seneciella, attack tansy ragwort seeds in Europe, markedly reducing the rate of spread of this plant. Adequate research in Europe has shown that the fly is host-specific. Approximately 16,000 puparia of the fly were gathered in the vicinity of Paris, France, in 1965, and adult flies from these puparia were released in Oregon and at Fort Bragg, California, in June 1966.

Haltica carduorum to control Canada thistle. A flea beetle, Haltica carduorum, which attacks Canada thistle in Europe, was released in Canada after adequate tests proved it would complete its development on the thistle only. Further proof of the beetle's specificity was obtained by means of an additional two-year study at Albany, California. The beetle was released at ten locations in 4 States in April, May, and June 1966.

The Alabama station in research on the sex attractants of the female cabbage looper moth, has isolated and identified an attractive chemical - CIS-7-dodecen-1-d acetate. The chemical structure of the attractant was verified by synthesis of the compound.

Mosquito Oviposition Lure. The Delaware station was successful in the isolation of a chemical substance possessing a high degree of attractiveness to ovipositing female mosquitoes, Culex salinarius, Coq. This attractant material is of protein origin, apparently derived from decaying plant tissues. Early in the investigation it was observed that concentrated straw infusion contained an attractant factor. In field and Laboratory tests, water suspensions containing a proteinaceous extract attracted more ovipositing mosquitoes than did the raw infusion, and significantly more than the native habitat. The oviposition lure which has been isolated should be very useful in the future in highly selective control measures for the mosquito, C. salinarius. The results indicate the way to develop similar lures which would be attractive oviposition sites for other species of mosquitoes.

Imported Parasite Controls California Red Scale. The parasite, Aphytis melinus, was introduced into California from Pakistan. Studies by the California station over the last five years have shown that in many citrus areas of California, particularly near the coast, the parasite has almost completely replaced ineffective parasites of other species and now provides a high and satisfactory degree of red scale control without the use of pesticides.

Parasite Controls Rhodesgrass Scale in South Texas. A microscopic wasp from India, some frozen food cartons and the airplane are being turned against a scale insect that has virtually obliterated Rhodesgrass, a favorite grass of ranchers for many years, and reduced the yield of other grasses in Texas. In some cases, the capacity of pastures was reported to have been reduced by 30 percent. Texas Agricultural Experiment Station entomologists have known the effectiveness of using the wingless wasp to parasitize Rhodesgrass scale for some time. Now, large areas have been needed with grass sprigs infested with scale, which in turn, are parasitized by the wasp. The grass sprigs are dispersed by dropping them in frozen food cartons from low-flying aircraft as in the screwworm eradication program. The parasites emerge from the grass sprigs and attack the scale in the area. Experimental drops have shown remarkable reduction in scale populations and substantial increases in forage yields.

Washing Removes Pesticide Residues. An intensive study of the effectiveness of washing fruits and vegetables with water and various detergents for the removal of certain surface residues, is in progress at the New York State Agricultural Experiment Station. During the past year, preliminary studies were undertaken for the removal of captan, parathion, and methoxychlor from Hudson cherries, DDT from apples, and endrin from cole crops. In all cases significant reductions in the surface residues could be accomplished without alteration of keeping quality of the produce.

As a step toward implementation of the recommendations for a National Program of Research for Agriculture made jointly by the Association of State Universities and Land Grant Colleges and the USDA, a section has been added to each of the Areas in this report. It comprises a list of the related publications of the State Agricultural Experiment Stations in addition to those heretofore reported covering the results of USDA and cooperative research. In future years, it is anticipated that information will be available to permit reporting of achievements resulting from State research in a format comparable to the present reporting of the USDA and cooperative research.

AREA NO. 1. VEGETABLE INSECTS

Problem. More effective, economical, and less objectionable methods of controlling insect and mite pests of vegetables in the field without leaving undesirable residues on or in the marketed product or in the soil, and without affecting the flavor or quality of the product, or adversely affecting beneficial insects, are the major objectives of this research. Insects and mites are important limiting factors in the production of high-quality vegetables. These pests reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase the cost of production. Use of insecticides and miticides is currently the most effective direct method of control; however, application too close to harvest may result in residue problems. There is concern over the possibility of contaminating animal products by feeding crop refuse or byproducts of peas, beans, sweet corn, or other vegetables treated with insecticides to livestock. Drift of certain insecticides into non-target areas may also cause problems. A number of vegetable insects have developed resistance to certain insecticides. Research is needed on methods for better utilization of predators, parasites, and diseases of vegetable insects and mites; bioenvironmental and cultural methods; development and utilization of more effective traps and lures; new approaches to control including radiation, chemosterilants, and antimetabolites; evaluation of insecticide application equipment; and the practical integration of non-chemical and chemical methods in area control of vegetable insect and mite pest populations. Additional emphasis should be placed on research to develop vegetable crops resistant to insects and to determine the factors responsible for resistance when found. Research is needed on insect vectors of vegetable diseases and the role they play in the dissemination of viruses. The heavy losses caused by viruses transmitted by insects to a variety of vegetable crops emphasizes the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program of applied and basic research on vegetable insects with stations at Mesa, Ariz., Riverside, Calif., Tifton, Ga., Twin Falls, Idaho, Lafayette, Ind., Beltsville, Md., Wooster, Ohio, Forest Grove, Oreg., Charleston, S.C., and Yakima, Wash., in cooperation with the respective State experiment stations and industry. Much of the work is in cooperation with the Crops Research, Pesticides Regulation, and Agricultural Engineering Research Divisions. Work in Idaho is also cooperative with the Idaho Bean Commission and that in Maryland with the Northern Utilization Research and Development Division and the Human Nutrition Research Division. Work in Oregon is conducted jointly with the Agricultural Engineering Research Division. Research is being conducted in Louisiana under contract to the Louisiana Agricultural Experiment Station and in Indiana under a research grant to the Indiana Agricultural Experiment Station.

Work in Karaj, Iran, on insects affecting vegetable legumes is supported with funds supplied by the Agency for International Development (AID) under the grain legume production project in cooperation with the Crops Research Division, the Soil and Water Conservation Research Division, Karaj Agricultural College, the Iran Ministry of Agriculture and the Iran Plan Organization. The Department also furnishes periodic consultant service on bean and other vegetable insects to the Ministry of Agriculture in El Salvador.

The Federal scientific effort devoted to research in this area totals 24.1 scientific man-years. Of this number 2.1 is devoted to basic biology, physiology, and nutrition; 3.5 to insecticidal and cultural control; 4.1 to insecticide residue determination; 4.5 to biological control; 2.9 to insect sterility, attractants, and other new approaches to control; 1.7 to evaluation of equipment for insect detection and control; 3.7 to varietal evaluation for insect resistance; 0.3 to insect vectors of diseases; and 1.3 to program leadership.

In addition Federal support of research in this area under contracts and grants provides 1.2 man-years. Of this total, 0.2 is devoted to biological control; 0.6 to insect sterility, attractants, and other new approaches to control; and 0.4 to varietal evaluation for insect resistance.

Three projects have recently been initiated under PL 480 research grants. These include research in India on Indian Jassidae with particular reference to Circulifer and related genera and their importance as vectors of plant virus diseases (Project A7-ENT-22) and on physiological factors governing susceptibility or resistance of crop plants to leafhoppers (Project A7-ENT-44) and in Israel on factors influencing variations in resistance of insects to insecticides (Project A10-ENT-13).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 49.0 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Cabbage Looper. When dye-marked male cabbage looper moths were released in the center of an 0.8 square mile area throughout which 15 blacklight traps were distributed at Riverside, Calif., recoveries decreased with increasing distance from the release point. Over 90% of the captured released moths were in traps within 1 mile of the release point. However, a few moths were caught 10,000 feet away.

When 1-day-old male moths were released, none were recaptured the night of the release. When 4- to 5-day-old male moths were released, 12.2% were recaptured on the night of the release. Fifty percent of the total recaptured were taken within 1.5 days after release and 90% within 4.3 days. Low

numbers of released male moths were caught up to 7 days after release. Total male cabbage looper populations estimated in July, October, and November ranged from 504 to 54 male moths per acre. Peak catches of wild cabbage looper moths per night per trap occurred in July in 1965 in contrast to August in 1964. Moth catch per night per trap decreased sharply a month earlier in the fall and increased about a month earlier in the spring in 1965.

Blacklight traps operated in each case for 2-hour intervals starting at 6 p.m. and ending at 6 a.m. showed that 58% of the male moths were caught in traps operated between midnight and 4 a.m., 15% and 16% from 10 p.m. and 12 p.m. and 4 a.m. to 6 a.m., respectively, and only 5% and 6% from 6 p.m. to 8 p.m. and 8 p.m. to 10 p.m., respectively.

At Mesa, Ariz., weekly releases of marked laboratory-reared cabbage looper moths were made starting in June 1965 in a 100-square-mile study area within which 25 15-watt blacklight traps were spaced at 2-mile intervals. Releases were made at 2-mile intervals with 16 release points 1.4 miles from each trap; at 1-mile intervals with 81 release points 75 feet and 1 mile, respectively, from each trap; and at a central release point. Releases consisted of 100 marked moths at each point except the central release. Here the releases varied with the numbers of moths available but usually amounted to several thousand at a given time. From release and recovery data different methods of population estimates are being investigated based on the ratio of released marked moths recovered to native moths trapped. Flight distances and time required to fly certain distances have also been investigated, as well as direction of flight. Of 27,357 moths released in the center of the area between June and November 1965, 0.16% were recovered, 70% of which flew in an easterly direction.

Flight of cabbage looper moths of various ages were tested in a flight meter in the laboratory at Riverside, Calif., when fed 10% sucrose, distilled water, or starved. Irrespective of the moth age, flight of male moths when fed distilled water or starved was 30% and 51% less, respectively, than the flight of moths fed 10% sucrose. Under the same conditions female-moth flight was 40% and 57% less, respectively, than the flight of females fed 10% sucrose. The maximum distances traveled by distilled water fed and starved male moths in 24 hours were 32.82 and 17.72 miles, respectively. The maximum distances for comparable female moths were 28.46 and 28.61 miles. Flight of 3-day-old male cabbage looper moths fed 1% tepa in 10% sucrose solution or sprayed with 1% tepa and fed 10% sucrose was decreased 76% and 48%, respectively, when compared to moths fed 10% sucrose without tepa.

Wheat bran and cottonseed meal were promising as the plant products in the cabbage looper larval diets in tests made at Riverside, Calif.

Also at Riverside, Calif., laboratory studies showed that no cabbage looper mating occurred below temperatures of 60° F. Reduced mating occurred at 60 and 90° F during the first 24 hours of confinement. Mating occurred most

frequently at temperatures of 70 and 80° F. Little or no oviposition occurred at temperatures below 60° F. The total numbers of eggs laid by moths held at 60, 70, 80, or 90° F were not significantly different; however, at 60° F fewer eggs were laid per 2-day oviposition period and the number of days moths oviposited was extended. Longevities of males and females at 40, 60, 70, or 90° F were not significantly different although there appeared to be a tendency toward decreased longevity with increasing holding temperatures. Moths of both sexes held at 50° F lived an average of more than 30 days.

2. Noctuid Moths. At Mesa, Ariz., cabbage looper, alfalfa looper, beet armyworm, yellow-striped armyworm, corn earworm, and granulate cutworm moths collected in blacklight traps show that the seasonal peak of populations for all six of these species comes in August and September. Lettuce, cauliflower, brocolli, and cabbage are planted in late August or early September in southern Arizona. These noctuid insects are major pests of one or more of these crops. With the exception of the corn earworm, moths of all other noctuid species studied are present in low numbers during the winter and early spring months. Cabbage looper and corn earworm moth populations reach their first peak in April or May and then drop to a comparatively low level during June and early July before attaining high seasonal peaks in August and September.

3. White Cotton Root Aphid. At Yakima, Wash., thief and pavement ants were found attending white cotton root aphids. This aphid attacks the roots of various vegetable crops and is quite helpless, depending on ants for its care.

4. Cowpea Curculio. A technique was developed at Charleston, S.C., for rapid sex determination of cowpea curculio by visual examination of pupae.

5. Southern Potato Wireworm. Southern potato wireworm adults constituted 99.4% of the elaterids caught in a single 15-watt blacklight trap operated throughout 1965 in a vegetable-growing area at Charleston, S.C., and 97% of the elaterids taken in 8 similar traps during August and September 1965 in a tobacco-growing area. Trap studies indicated that southern potato wireworm adults will fly over a small farm pond and to a height of at least 100 feet over a wooded area. Larvae from cultivated soil samples taken in 18 fields on 10 farms during October and November 1965 were 99% southern potato wireworms. An average of 2.2 larvae per square foot to 6-inch depth were found; and 4.6% of the harvested potatoes from 12 farms showed wireworm feeding; 1.3% were sufficiently injured to be classed as "damaged."

6. Two-Spotted Spider Mite. At Beltsville, Md., two strains of the two-spotted spider mite, Cranbury-1 (parathion resistant) and Niagara (parathion susceptible), are being used to study biological activities that occur between strains. When virgin females of either strain mated with males of the same or opposite strain, resistance was transmitted to female offspring by either sex. When the mated females were exposed to males of the opposite strain for a second mating, Cranbury-1 females were not inseminated by the

second exposure. In contrast, Niagara females successfully mated a second time and resistance of their progeny indicated that the two matings were of equal importance. In mixed populations where the rate of Cranbury-1 to Niagara males was 1:1, Cranbury-1 virgin females showed a 9 to 1 preference for Cranbury-1 males over Niagara males and the Niagara females showed a 7 to 2 preference for Niagara males.

Cranbury-1 and Niagara females were placed on potted bean plants in proportions of 10 N - 0 C, 8 N - 2 C, 5 N - 5 C, 2 N - 8 C, and 0 N - 10 C. When tested at 5 intervals during the succeeding 10-week period, the mixtures of strains tended toward greater susceptibility at each sampling. Tests on progeny of individual mites revealed the presence of both homogeneous and heterogeneous individuals.

7. Mexican Bean Beetle. At Beltsville, Md., young virgin female Mexican bean beetles that had mated once produced fertile eggs for 4 to 5 weeks. When a virgin female was mated with an apholate-sterilized male, eggs did not hatch, but if remated with a normal male high fertility was restored to eggs laid subsequently. Egg fertility between weekly matings in which normal and sterilized males were alternated indicated a greater influence of the most recent mating but a holdover effect from earlier matings.

B. Insecticidal and Cultural Control

1. Cowpea Curculio. At Charleston, S.C., Bidrin, Bay 25141, Azodrin, and methyl parathion were the most promising of 12 compounds tested in field plots of southern peas for control of the cowpea curculio.

2. Squash Vine Borer. Carbaryl, naled, and endosulfan gave adequate protection to field plots of summer squash in South Carolina. Lindane was less effective but all materials controlled the pickleworm.

3. Cabbage Looper. At Charleston, S.C., of 45 experimental compounds compared in laboratory tests, nine showed sufficient toxicity to justify further study. In field tests seven were as effective or superior to naled and endosulfan on fall cabbage. On spring cabbage eight were as effective or superior to naled and endosulfan, and superior to mevinphos. Four, as used, were phytotoxic.

4. Southern Potato Wireworm. Thirty-four compounds were compared in laboratory tests in South Carolina for larval toxicity. The most promising were Dursban and Stauffer N-4328 and N-4988. In field-plot tests, Niagara NIA-10242 was the most promising material tested for southern potato wireworm control. Seven materials reduced larval populations 96% or more.

5. Leaf Miners. At Charleston, S.C., 28 compounds were tested for toxicity to leaf miner larvae in cowpea seedlings. Nine were promising for possible control.

6. Banded Cucumber Beetle. Of the 35 compounds tested in the laboratory at Charleston, S.C., six were somewhat effective against banded cucumber beetle larvae.

7. Sweetpotato Insects. Also at Charleston, S.C., Niagara NIA-10242, diazinon, Dursban, and Stauffer N-2790 were effective for southern potato wireworm control when applied as granules over the sweetpotato beds on July 15 and August 15 at 1.5 lb/acre of active ingredient on each date. One application of diazinon at 3 pounds on July 30 was less effective. Niagara NIA-10242 was the most effective against the Diabrotica-Systena complex but reduced injury only 50%. However, it was the only material tested which controlled sweetpotato flea beetle larvae.

8. Drosophila. At Beltsville, Md., technical malathion at 2 lb/acre showed promise for the control of drosophila on tomatoes. It was less effective than diazinon granules at 1 lb/acre but equal or superior to diazinon technical or malathion EC at 3/4 lb and 2 lb/acre, respectively. Malathion technical at 1 lb/acre gave poor control of drosophila.

9. Corn Insects. At Tifton, Ga., of the chemicals tested for control of corn earworm and fall armyworm, only Azodrin was significantly better than DDT. Niagara NIA-10242, Mobil MC-A-600, and Shell SD-7438 gave control equal to DDT.

Also at Tifton minimum improvement in control after treatment with DDT was found in sweet corn varieties resistant to the earworm. Maximum improvement in control was found in the susceptible varieties.

10. Mint Flea Beetle. At Forest Grove, Oreg., helicopter applications of low volume technical malathion on mint at rates of 6 and 8 ounces per acre reduced mint flea beetle populations 92% and 98%, respectively, for 14 days after application.

C. Insecticide Residue Determinations

1. Effect of Rain on Persistence of DDT on Sweet Corn. At Tifton, Ga., artificial rain was applied in 1-inch increments at rates of 0, 0.5, and 2.0 inches per hour to plots of sweet corn previously treated with DDT emulsifiable concentrate (2 lb DDT/acre). About 10% more DDT was lost from the higher rate of rainfall (2 in./hour) than from the lower rate (0.5 in./hour). The loss of DDT residues from the plot that received no artificial rainfall was much higher than expected, about 50% during the first day.

2. Chlorinated Hydrocarbon Residues in Farm Soils. Soil samples collected in October and November 1964 from 186 corn farms in the State of Iowa were analyzed at Beltsville, Md. Chlorinated hydrocarbon residues exceeding 0.01 ppm were found in soil from 74 farms. Aldrin was found in the samples from 34 farms, dieldrin from 61 farms, heptachlor or heptachlor epoxide from 15 farms, and DDT from 7 farms. The largest amount found was 1.8 ppm of aldrin

and 0.66 ppm of dieldrin in one sample. All but one grower indicated they had used chlorinated insecticides.

3. No Malathion and Diazinon Residues above Tolerance on Tomatoes. At Beltsville, Md., malathion and diazinon sprays were applied to tomato plants at approximately weekly intervals between September 3 and September 20, 1965. Samples for residue analysis were collected 24 hours after the first three sprays and 6 hours, 1 day, and 2 days after the final spray. The treatments were technical malathion, 1 and 2 pounds per acre; malathion emulsion concentrate, 2 pounds active per acre; technical diazinon, 0.75 pound per acre; and granular diazinon, 1 pound active per acre. No residues exceeding the established tolerances (diazinon, 0.75 ppm; malathion, 8 ppm) were found on tomatoes, even when samples were collected 6 hours after treatment.

At Beltsville, Md., an aerosol application of dichlorvos (10%) in methyl chloride applied to greenhouse tomatoes, cucumbers, and Bibb lettuce showed maximum residues of 0.24 ppm on lettuce and .02 ppm on tomato 1 hour after exposure. No detectable residues were found in 2-day or later samples.

Aerosols containing 10% sulfotepp showed residues of 0.20 ppm in lettuce, 0.12 ppm in tomato and 0.01 ppm in cucumbers 1 hour after exposure and 0.02 ppm in 7-day lettuce and tomato samples.

4. Tepa Residues. At Tifton, Ga., the GLC method was used to determine the persistence of tepa in fall armyworm moths after both sexes were fed 0.3% tepa in 10% aqueous sucrose. Moths ingested up to 100 µg and over 90 and 95% of the tepa had disappeared within 24 and 48 hours, respectively. About 1 µg of tepa per insect was recovered from the feces after 48 hours.

A felt wick insect feeding device continuously impregnated with 0.15% tepa and 2% aqueous sucrose was attached to ultraviolet light traps in the field. Samples of the solution and wick taken on the day of installation and after 1, 2, 3, and 5 days indicated that tepa in the aqueous secrose solution declined approximately 45% during the first 24 hours, and leveled off at about 50% of the original quantity during the next four days. Tepa in the wick diminished 20% during the first 24 hours, 53% by the end of the second day, and 86% by the end of the third day where it leveled off.

5. Residues in Sweet Corn. At Tifton, Ga., gas chromatographic techniques for analyzing residues of Azodrin and Bidrin in raw extracts of sweet corn showed that amounts as low as 2 ppb were detected without appreciable interference from the corn extract. Imidoxan and Imidan in corn silage and in sweet corn were detected at levels of 2 ppb (parts per billion) for Imidan and 4 ppb for Imidoxan.

D. Biological Control

1. Cabbage Looper. At Mesa, Ariz., rearing of cabbage looper larvae field-collected throughout the year in the Salt River Valley of Arizona revealed

a high percentage of parasitism by the tachinid fly, Voria ruralis. Parasites reared in the Mesa laboratory on looper larvae were released in four 12 X 24 X 6-foot field cages, each containing 150 lettuce plants infested with 300 looper larvae. Ten, 50, and 175 pairs of introduced Voria adults parasitized 4%, 13%, and 57%, respectively, of the sampled larvae. None of the larvae in check cages was parasitized.

At Riverside, Calif., the presence of formaldehyde in the larval diet in laboratory studies reduced the infectivity of cabbage looper polyhedral inclusion bodies (PIB). This effect was manifested by a 53-fold increase in the LD_{50} values as well as an increase of almost 2 days in the time to reach the LT_{50} values. The susceptibility of cabbage looper postlarval stages to nuclear polyhedrosis virus infection gradually decreased until adulthood was reached. Moth infections were obtained by using free virus preparations. Histological studies of the moths in which polyhedral inclusion body preparations were fed or injected did not reveal the presence of infection. Infected progeny were obtained from moths fed polyhedral inclusion body suspensions. Injected moths did not yield infected progeny.

At Charleston, S.C., 3 weekly combination spray applications on field cabbage plots of cabbage looper nuclear polyhedrosis virus at 100 billion polyhedra per acre plus 1 qt/acre of commercial Bacillus thuringiensis liquid formulation were preceded by 1 application of the virus alone; on harvesting 50% of the plants were free from cabbage looper and fall armyworm injury and were classed ineligible for U.S. Grade 1 because of damage. In a comparable untreated planting 5% were free from damage and 52% were rejected for U.S. Grade 1. In 1966 spring-crop field tests, 6 weekly spray applications of the virus at 6 trillion polyhedra per acre plus 1 qt/acre of the B. thuringiensis formulation were as effective as an endosulfan-parathion mixture in control of imported cabbageworm and larvae of the diamondback moth, but less effective against the cabbage looper. In virus-bacillus sprayed plots 4% of the plants were ineligible for U.S. Grade 1 because of caterpillar damage, as compared to 2% in endosulfan-parathion mixture sprayed plots and 88% in untreated plots. The bacillus formulation alone did not give adequate control of looper.

In laboratory studies several commercial formulations of B. thuringiensis and the axenic cultures prepared therefrom were found to be at least partially repellent to larvae of the cabbage looper and the imported cabbageworm. Observations and field collections of cabbage looper larvae showed a high percent of natural infection by the fungus Spicaria rileyi. Eighty-one immature cabbage looper larvae were collected and held in individual vials for observation. Fifty-seven percent died as a result of the fungus and 5% were killed by larvae of the hymenopterous polyembryonic parasite Copidosoma truncatellum.

2. Pea Aphid Parasites. An experiment was conducted in the Walla Walla, Wash., area to determine whether overflooding of the pea aphid population in alfalfa fields with large numbers of parasites would prevent the annual

migration of this aphid to the more than 60,000 acres of green peas grown in adjacent areas. Approximately 100 million small wasplike parasites (Aphidius pulcher Baker) of the pea aphid were reared in heated plastic film-covered cages in alfalfa fields in the spring of 1966 and released. Production and release of parasites continued during spring and early autumn. The cages provided an abundance of parasites long before they would normally be available. The released parasites invaded approximately 15,000 acres of alfalfa. Pea aphid migration to peas was reduced to an insignificant level requiring no insecticidal treatment. The pea aphid spreads the destructive pea enation virus in pea fields and causes damage to peas by its feeding.

Approximately 22 million parasites per acre were raised on pea aphids in each of 18 plastic film-covered cages on a mixture of Atlantic and Vernal varieties of alfalfa. Buffalo, Ranger, and Caliverde alfalfa varieties were the most prolific of 30 tested for mass production of aphids for rearing parasites.

3. Banded Cucumber Beetle. At Charleston, S.C., 3 sprays of the parasitic nematode DD-136 were applied to field plots to give 2500 or 5000 nematodes per quart of soil to a 6-inch depth. Mortalities were 80 and 92%, respectively, of banded cucumber beetle larvae placed in samples of the soil 4 days after the last application decreasing to 28% for both dosages after 30 days.

4. Aphids. Collections of diseased aphids on different plant species in South Carolina revealed that several species of fungi of the genus Entomophthora are infecting and possibly influencing aphid abundance in the vicinity of Charleston.

5. Mexican Bean Beetle. In laboratory tests at Charleston, S.C., Metarrhizium anisopliae killed 100% of the first-instar larvae of the Mexican bean beetle after 72 hours. This fungus was not found to be pathogenic to the adult or egg stages of this insect.

6. Other Insect Pathogen Studies. Also in South Carolina, 6 fungi evaluated as pathogens against second instar banded cucumber beetle larvae were Metarrhizium anisopliae, Aspergillus ochraceus, Acrostalagmus aphidum, Entomophthora coronata, Entomophthora sp., and Cladosporium sp. Only Metarrhizium anisopliae displayed potential value as a control agent. Mortality observed was 5, 70, and 100% after 24, 48, and 72 hours, respectively.

7. Corn Earworm. Two commercial preparations of a Heliothis virus were compared in the laboratory at Charleston, S.C. Neither was highly toxic to corn earworm larvae. One gave 42.7% mortality after 10 days, the other 16.7%. Mortality in the untreated cages was 4.4%.

8. Corn Insects. At Tifton, Ga., preliminary results on the effects of temperature and dosage on the pathogenicity of the fall armyworm nuclear-

polyhedrosis virus indicated higher total larval mortality at 22-25° C than at 29-31° C. Peak and final mortalities occurred later at the lower temperature than at the higher temperature.

E. Insect Sterility, Attractants and Other New Approaches to Control

1. Cabbage Looper. The number of male cabbage looper moths caught increased with increasing numbers of virgin female moths confined in cages attached to blacklight traps in tests at Riverside, Calif. The mean numbers of males caught per night per 3 blacklight traps with 0, 12, 24, 48, or 96 virgin female moths were 12, 38, 100, 117, and 286, respectively. The number of female moths caught in the baited blacklight traps was not affected. When cages containing virgin females were placed (1) on the trap, (2) 40 feet away, (3) 80 feet away, or (4) 160 feet away from the trap, traps with caged virgin females on the trap or 40 feet from the trap caught significantly more male moths than unbaited traps or baited traps with the virgin females placed 160 feet from the trap. The regression of male catches on distance of virgin females from the trap indicates that the catch was reduced approximately 1 male per night per trap for each foot in distance the virgin females were placed away from the trap within the range of 0 to 160 feet. When marked males were released, 95% of the moths recaptured were caught in the virgin female baited traps.

To determine whether sex pheromone alone and/or other factors were involved in the attractiveness of the female baited blacklight traps, experiments were conducted with unmated cabbage looper males, virgin females with abdomens enclosed in gelatin capsules, equal number of males and females in a common cage, and virgin females alone. Traps baited with males or females with gelatin encapsulated abdomens were not as effective as virgin female baited traps. Mixed sex baited traps were as effective as virgin female-baited traps on the first night but effectiveness decreased thereafter.

Blacklight traps with 6- or 15-watt fluorescent lamps caught approximately equal numbers of male and female cabbage looper moths. Blacklight traps baited with virgin female moths caught more males than the unbaited traps. Traps with 15-watt fluorescent blacklight lamps and baited with virgin females caught nearly twice as many male moths as the 6-watt trap baited with virgin female moths.

At Riverside, Calif., the synthesized female cabbage looper sex pheromone was incorporated in a sand carrier in 100, 1000, 10,000, or 100,000 µg amounts and tested for effectiveness in the field in combination with blacklight traps. Traps baited with 100,000 µg of the synthesized pheromone caught 13 times more males than unbaited blacklight traps and about 2 times more than blacklight traps baited with 100 virgin females. At the end of 30 days, the former was still more effective than the latter. Traps baited with 100, 1,000, and 10,000 µg were more effective than unbaited traps up to 9 days under field conditions.

At Charleston, S.C., an 8% concentration of apholate sterilized male cabbage looper moths when exposed for 15 minutes to dried residue on glass.

2. Cucumber Beetles. At Charleston, S.C., 126 fractions of extracts of 40,527 virgin female banded cucumber beetle abdomens were bioassayed as male attractants. Pollen was found to be a necessary ingredient in the diet of spotted cucumber beetles for the production of a male lure by the females. When crude extracts of spotted cucumber beetle and banded cucumber beetle females were mixed, male response of the former was decreased by about 50% and the latter showed no measurable activity. There was evidence that the residual half-life of the spotted cucumber beetle attractant on filter paper was less than 1 hour. This is in contrast to that of the banded cucumber beetle, which remains active for several days. Active extracts were obtained from spotted cucumber beetle females up to 24 hours after they had mated. Extracts from banded cucumber beetle females immediately after mating were inactive. No evidence of a sex attractant in the striped cucumber beetle was found.

Concentrations of 0.5 and 1% apholate in buffalo gourd extract sterilized males when they fed on the residues on filter paper or strips of fiber glass. A concentration of 0.25% was partially effective. Hydroxy urea at 1% was ineffective. General Chemical compounds 6936 and 8993 at 1% were highly toxic to males. An electronic flash was ineffective as a sterilant when males were exposed at a distance of 1.5 inches from a 1/1500 second flash.

3. Squash Insect Control. In South Carolina a soil mulch of reflective aluminum foil reduced by 82% the number of banded cucumber beetles that flew into a planting of yellow straightneck summer squash and reduced by 87% the number of seedlings showing their feeding. The number of aphids that flew into the field was reduced by 96%, the number of pickleworm-infested fruits by 72%.

4. Mexican Bean Beetle and Aphids. Overwintering adult Mexican beetle migrations to plots of snap beans were reduced 92%, 84%, and 51% when plots were mulched between rows with 2-foot-wide peg board covered with aluminum, titanium white paint, or dull black paint, respectively, in comparison to unmulched plots in tests at Beltsville, Md. Reductions of aphids caught in yellow water traps were comparable.

5. Trapping Studies. At Beltsville, Araujia sericifera flowers caught the same insect species as in 1964. Blacklight traps installed near the Araujia vines and 100 feet away, caught equal numbers of insects at both locations. Most of the insects were caught in the blacklight traps.

6. Drosophila. At Beltsville, Md., 2% apholate in bait on vermiculite broadcast over tomato plants in screen cages gave a maximum of 90% reduction over untreated controls. Approximately 72% of females collected from the apholate-vermiculite plots during the season were sterile. The vermiculite bait containing 2% apholate gave better control than 2% apholate on 1-inch

Oasis Foam cubes distributed 1 cube to every 4 feet of row but was not superior to tepa or ENT 50905 at the same concentrations on Oasis Foam cubes.

In laboratory screening tests at Beltsville, a bait containing 2% of the chemosterilant ENT 50905 gave high sterility of male Drosophila melanogaster adults for about 2 weeks; but was ineffective against female flies. A bait containing 1% apholate gave high sterility of both sexes for about 25 days.

F. Evaluation of Equipment for Insect Detection and Control

1. Southern Potato Wireworm. At Charleston, S.C., a 15-watt fluorescent blacklight trap caught 19,319 southern potato wireworm adults during 13 nights in August, significantly more than in traps with green, daylight, or strontium blue lamps. The last named lamp caught the least number of beetles. No significant differences were found between the catches of adults in blacklight traps placed 2, 4, 6, 10, or 18 feet above ground level. Overwintering larval populations of the southern potato wireworm were not significantly reduced in the soil within 100-foot radii around 15-watt blacklight traps operated throughout the preceding summer and fall.

2. Corn Insects. At Tifton, Ga., conventional insecticides applied every day gave better corn earworm control than insecticides applied every-other-day or every third day. Applications on an alternate day schedule were significantly better than applications made every third day.

Also at Tifton a tractor-mounted system for applying technical or concentrated formulations, at extremely low volumes was developed. One system is capable of applying the toxicant at rates as low as 1 pint per acre. The other system will apply toxicants as low as 1 quart per acre.

At Tifton, Ga., engineers have continued to refine a system utilizing air streams to separate insects on a weight and shape basis. Combined with an ultraviolet light trap, the unit increases the efficiency of the trap and can be used to collect desired species from the total night-flying population.

3. Helicopter Spray Studies. At Forest Grove, Oreg., water-based dye sprays were applied with a Bell 47D-1 helicopter using a 48-foot boom with 41 flat spray nozzles symmetrically arranged. The helicopter was flown at a height of 8 feet at speeds of 30, 42, and 54 miles per hour. Spray recovery data showed that when the speed of the helicopter was increased from 30 to 54 mph with the discharge rate remaining the same, the deposit rates on the top surfaces of target plates were reduced approximately one-half and on the under surfaces by about two-thirds.

Helicopter tests conducted in cooperation with the U.S. Forest Service, showed that where Douglas fir trees were sprayed at rates of 1 and 3 gal/acre with water-based dye sprays, the average recovery was .3 and .63 gal/acre, respectively, in the tree crowns. Recovery at the ground level among the trees was .14 and .6 gal/acre, respectively, at the two rates. Spray

coverage was most uniform at the 3 gal/acre rate, but the spray droplet size range was much greater. There was no significant difference in the amount of spray recovered at the top, middle, and lower crown positions within the trees.

Trees sprayed with a fluorescent tracer spray at 1 and 3 gal/acre had an average of 1.4 and 5.4 droplets deposited per 10 needles. Average deposits of the fluorescent tracer were 45, 30, and 25% of the total droplets at the top, mid-crown, and lower crown levels, respectively. During these studies Calcofluor white used with suitable recovery targets proved useful for evaluating spray patterns, distribution, droplet size, and foliage penetration.

Spray deposit spot sizes of the fluorescent at the 3 gal/acre rate ranged from 27 to 1410 microns with a mean of 456 microns and for the 1 gallon rate from 78 to 1210 microns spot size with a mean of 339. Results were similar with water-base dye sprays. There were fewer spots per unit area on the targets treated at the 1 gal/acre rate but proportionately more were in the mid-range of micron size than for the higher application rate of 3 gal/acre. These comparisions of the two application rates all seem to indicate that there would be a much higher percentage of droplets in the more useful size range at the lower rate.

In cooperation with the U.S. Forest Service a field test was conducted during the summer of 1965 to determine virus spray dosage and concentrations required for control of the Douglas-fir tussock moth. Three different virus polyhedra rates were applied by helicopter in 1-gallon and in 3-gallons of spray per acre. Spray was applied at 5 weekly intervals to potted trees, subsequently colonized with larvae to determine pathogenicity of the different treatments. Applications of 1, 5, and 50 billion polyhedra per acre in one gallon per acre were as effective, or slightly better, than applications of the same virus rates in three gallons per acre. The 50 billion polyhedra per acre rate was sufficiently effective to indicate a satisfactory control potential. All applications were most effective against second-instar larvae.

After the initial wave of polyhedrosis resulting directly from virus applications, waves of polyhedrosis occurred subsequently at about two-week intervals; apparently due to natural contagion and spread of the disease from those dying as a direct result of the virus applications.

H. Varietal Evaluation for Insect Control

1. Pepper Weevil. At Riverside, Calif., eighty-two selections from third generation crosses of wild vs. commercial type chili peppers were studied for resistance to pepper weevil attack. Individual pods from 25 plants from each of the 82 selections were examined for pepper weevil damage. Mean number of infested pods per selection varied from a low of 0.05 to a high of 16.60.

2. Leafhoppers. In preliminary studies in India (PL 480 Project A7-ENT-44) to determine the mechanisms involved in host plant resistance to certain leafhoppers of the genus Empoasca, castor bean plants, (Ricinus communis) were found most suitable for development of the leafhopper, E. kerri var. motti Pruthi, followed by cotton (Gossypium hirsutum) and potato (Solanum tuberosum) in that order. G. herboceum and G. arboreum were less suitable hosts of the leafhopper than cotton.

3. Two-Spotted Spider Mite. At Yakima, Wash., of 10 squash bug resistant hybrid lines of squash, two were very susceptible and two very resistant to attack by two-spotted spider mites.

4. Cabbage Looper. Field observations at Charleston, S.C., indicated S.C. Breeding Line 35 and Early Round Dutch cabbage to be least susceptible to cabbage looper feeding. Greenback, Steins Early Flat Dutch, Charleston Wakefield, S.C. Breeding Line 38, Red Acre, Marion Market, Jersey Wakefield, Midseason Market, Golden Acre, and Early Glory were an intermediate group, and Copenhagen Market No. 86 and Badger Market were most susceptible. The percentage of plants of these varieties showing serious injury by loopers ranged from 0 in case of S.C. No. 35 to 58.9 for Badger Market.

5. Soil Insects. L3-64 sweetpotatoes continued to be most resistant to soil insect attack of 40 varieties or breeding lines tested in the field at Charleston. Nemagold, also showed outstanding resistance to all of the soil insects present, except possibly the sweetpotato flea beetle. Several other breeding lines showed fairly high resistance, but all other commercial varieties were seriously injured. There was good agreement in the performance of lines that were tested in 1964 and 1965. Laboratory studies indicated at least two insect resistance factors in sweetpotato roots, one in the skin and another in the flesh. Either factor alone does not afford much protection in the field. There was evidence that the resistance factors were transient in at least some of the varieties.

6. Banded and Striped Cucumber Beetle. Also at Charleston, S.C., it was found that at least four of the cucurbitacins, a group of bitter compounds found in wild and cultivated cucurbits, are feeding stimulants for the banded cucumber beetle. These compounds elicit a strong biting response from the adult beetles when impregnated on filter paper and appear to be a major determining factor in preference shown by the insect for certain cucurbit crops and varieties. The striped cucumber beetle did not respond to the cucurbitacins tested on filter paper, and preliminary studies indicate there are other factors of greater importance as a basis for preference.

7. Drosophila melanogaster. Ripe tomatoes from 18 varieties were compared for their attractiveness to egg-laying adults of Drosophila melanogaster at Beltsville, Md. Higher number of eggs were laid in fruits of Pinkdeal, Manalucie, and High Crimson than in Roma, VF 13L, and VF 145B.

8. Leaf Miner. At Beltsville, Md., leaf miners showed a marked preference for oviposition in wild type tomatoes No. 128653 and No. 128655. The tomato types No. 126445 and 127826 were completely resistant to L. munda. No evidence of feeding or egg laying was noted for these two varieties even when placed alone in cages containing numerous adults.

At Beltsville, Md., of 33 tomato varieties tested when 8 weeks old, leaf miner larval survival in 26 varied from 91 to 80%. In the 7 remaining varieties larval survival was 74 to 80% in varieties No. VF 145B, Delshar, Floralon, and Kalohi; 64 to 68% in Chico and No 63B922; and 57 to 60% in Roma and Harvester. When 10 of the same varieties were retested as 10-week-old plants. larval survivals were 25, 27, 34, and 36% in Harvester, Chico, Roma, and No. 63B922, respectively. Larval survival of 94% in the primary leaves of nonresistant lima beans was a basis for comparing resistance in the tomato varieties.

9. Corn Insects. At Tifton, Ga., results showed that the husk, silks, and kernels contributed to the amount of insect feeding on kernels. Inbred 166 had good husk resistance for sweet corn but poor silk and kernel resistance. Inbred 245 had an extremely long husk but owes most of its resistance to silks. Inbred F-6 seemed to have good resistance in all three areas and transmits its resistance to progeny when used in hybrids. PI 217413 owes part of its resistance to the low survival of early instar larvae. Pollination of silks increased larval survival. Slitting the husk of pollinated ears further increased survival and average larval weights. Inbred 245 had significantly small larvae.

At Lafayette, Ind., cross and the reciprocal cross of the two inbreds most resistant to earworms produced the most resistant progeny in a diallel cross study. However, the cross and the reciprocal cross between the two inbreds most susceptible to earworms did not produce the most susceptible progeny.

At Tifton, Ga., of 20 sweet corn lines and 32 corn lines from South and Central America screened for leaf damage by fall armyworm larvae, some resistance was apparent in Zapalote Chico, Zapalote Grande, and Antiqua 2-D.

Diet utilization studies of lyophilized corn leaves, silks, and kernels by third instar fall armyworm and corn earworm larvae indicated a wide range in utilization of the lines screened. Fall armyworm larvae utilized only 21% of the leaves of inbred 360, while 42% of the leaves of inbred 230 were utilized. In general, the fall armyworm utilized corn leaves slightly better than the corn earworm. Results with the kernel diets indicated a difference ranging 20 to 50% for the fall armyworm and from 41 to 53% for the corn earworm. In general, there was a higher utilization of the diets by the corn earworm than by the fall armyworm. Kernels were more highly utilized than silks by both species of insects.

A larval arrestant and feeding stimulant extracted from kernels, silks, and leaves of selected lines of corn was screened for responses from corn earworm and fall armyworm larvae. Leaf extract had the most feeding stimulation for

fall armyworm and the least for earworm, while the kernel extract stimulation response was reversed. Silk extracts were intermediate for both species of insects.

Kernel extract on leaves seemed to give the highest level of holding ability for corn earworm larvae in a preliminary laboratory test, but silk and leaf extracts when placed on leaf substratum also significantly arrested motion and stimulated feeding. In contrast, the fall armyworm fed as readily on untreated leaves as on leaf surface treated with leaf, kernel, or silk extract, indicating that the maximum feeding response for this larva was already present in leaves.

Hickory tussock moth larvae were not stimulated to feed by kernel extract beyond the response to sugar. Toad flax extract did not elicit a strong feeding response from the corn earworm or fall armyworm.

Results of feeding stimulant tests with kernels with high (ae gene) and low (wx gene) amylose, low starch (super sweet), high and low protein, high and low lipids, and high and low carotene indicated that high amylose gave the highest feeding stimulant response for fall armyworm and corn earworm. Low amylose gave the smallest amount of feeding stimulant response for the fall armyworm.

Adding feeding stimulant to rearing medium increased fall armyworm larval weights and survival but did not effect corn earworm larvae.

I. Insect Vectors of Diseases

1. Aphids. Aluminum foil used as a soil mulch at Beltsville, Md., was superior to black polyethylene mulch or parathion spray in preventing infection of squash plants by watermelon mosaic virus. Flying aphids were reduced 93% over aluminum and 41% over black plastic as compared to the check during light aphid flights. After 11 weeks, percentages of virus infected plants were 4, 51, and 69 for aluminum, black plastic, and unmulched check, respectively.

During heavy aphid flights virus infection was delayed for several weeks by aluminum but not by parathion sprays. Yield of harvested squashes was about 6 times greater in mulched plots than in sprayed plots or the unmulched check.

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AREA NO. 2. POTATO INSECTS

Problem. Control of insect pests is essential to the profitable production of high-quality potatoes. There is a continuing need for research to improve present control methods as insects develop resistance to insecticides and the public demands safer, more effective, and more economical methods of insect control. The overall problem is complicated in that many of the virus diseases of potatoes are transmitted by small populations of insects that otherwise would be of little importance. Sometimes it is not known which insects are responsible. It is important to learn the identity, distribution, and ecology of the vectors of diseases of potatoes in order to make an intelligent approach to the development of methods for preventing insect transmission of the diseases. There is an especial need for research on the ecology and biological control of potato insects; and for research on the evaluation of potato varieties for insect resistance. Growing concern over problems associated with insecticides which may also include residues in the soil, contamination of non-target areas, and interference with the work of natural enemies of insect and mite pests, requires that an increasingly strong research effort be concerned with development of non-chemical methods of insect control or of ways of using chemicals that will avoid objectionable side-chain effects.

USDA AND COOPERATIVE PROGRAMS

Basic studies on the biology, ecology, and pathology of insects that attack potatoes in the field or transmit virus diseases, as well as applied research on their control are conducted by the Department at Yakima, Wash., Orono, Maine, Beltsville, Md., and Charleston, S.C., in cooperation with the respective State experiment stations, the Washington Department of Agriculture, the Washington State Potato Commission, and industry. In cooperation with the Crops Research Division studies on plant resistance are conducted at Ames, Iowa, under a grant to the Iowa State University of Science and Technology. Biological control studies at the University of Maine are conducted under a cooperative agreement.

The Federal scientific effort devoted to research in this area totals 4.6 professional man-years. Of this number 0.3 is devoted to basic biology; 1.7 to insecticidal and cultural control; 0.7 to insecticide residue determinations; 1.2 to biological control; 0.1 to evaluation of equipment for control and detection; 0.3 to insects that spread potato diseases; and 0.3 to program leadership.

In addition Federal support of research in this area under grants and cooperative agreements totals 1.2 man-years. Of this total 0.7 is devoted to biological control and 0.5 to plant resistance to insects.

Research under the PL 480 grant program is being supported in India and Poland. Projects in India include research on hereditary variation in the ability of Myzus persicae to transmit potato leaf roll and virus Y (A7-ENT-33) and on physiological factors governing susceptibility or resistance of crop plants to leafhoppers (A7-ENT-44). In Poland research is underway on the influence of fatty acids and alpha-tocopherol on the lipid metabolism and physiology of the Colorado potato beetle and on vitamin activity in coming generations (E21-ENT-18).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 4.3 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Aphids. At Presque Isle, Maine, aphid populations in 1965 were not large enough to reduce the total weight of tubers produced by untreated potatoes of the Katahdin or Kennebec varieties. However, the number of very small tubers (under $1\frac{1}{2}$ in. diameter) was increased as a result of aphid feeding damage. Untreated Kennebecs substantially outyielded untreated Katahdins under competitive conditions.

Initial populations of the potato aphid in 1966 were average; however, an epizootic of entomogenous fungi occurred in August which greatly curtailed their potential development. The green peach aphid was more abundant than usual but buckthorn and foxglove aphids were scarce.

The number of aphid eggs in November 1965 on alder-leaved buckthorn, primary host of the buckthorn aphid, was the smallest on record since 1943. Colonies of green peach aphids were found in only 2 out of 26 thickets examined.

B. Insecticidal and Cultural Control

1. Aphids. At Presque Isle, two foliar applications of endrin made before the end of July reduced leaf roll in the Katahdin variety potatoes with 10% infector plants to only 1/9th that which occurred in untreated potatoes. This 2-spray treatment was far superior to one or two applications of UC-20047A at 0.25 or 0.5 lb./acre or plots receiving a planting furrow application of the systemic insecticide, disulfoton, at 1 lb./acre.

Best control of leaf roll spread from planting furrow applications of systemic insecticides was obtained with 0.5 lb./acre of disulfoton mixed with 0.5 lb./acre of Bay 25,141. Leaf roll spread from this treatment was only 0.6%, as compared with 1.6% from a seed dip of 2 or 4% Bidrin, 3.6% from 1 lb./acre of phorate, 3.2% from 1 lb./acre of Bay 25,141, or 4.2% from 1 lb./acre of disulfoton. The Bidrin dip injured the potato seed-pieces.

Single applications to potatoes , when 50-90% of the plants were aphid infested, of sprays containing UC-20047A at 0.5 lb./acre or a mixture of methyl parathion and endrin, each at 0.2 lb./acre provided aphid control, preventing yield loss. Two applications of methyl parathion were required to achieve approximately the same degree of aphid control.

From 92 to 99% control of the green peach aphid was obtained in 48 hours from single foliar application of RP-11974 at 0.2 or 0.4 lb./acre, methyl parathion-endrin mixture (each at 0.1 lb./acre), Bay 25,141 at 0.2 lb./acre or ethyl parathion at 0.1 lb./acre. The degree of control from most materials was slightly reduced at 6 days.

Field tests with potatoes at Yakima, Wash., showed that disulfoton gave better control of the green peach aphid when granules were placed in the soil below the level of the potato seed-pieces than above them.

2. Two-Spotted Spider Mite. Azodrin gave outstanding control of the two-spotted spider mite, Tetranychus urticae (Koch), on potatoes when applied with either ground equipment or with airplanes at Yakima. No residues were found in potato tubers harvested 21 and 32 days after foliage treatments were made.

Sprays containing Zinophos, phorate, and Union Carbide UC-21149 applied to large plants infested with the two-spotted spider mite with ground equipment gave 98% control of the mite for 14 days.

C. Insecticide Residue Determinations.

1. No Organophosphorous Residues Found in Potatoes. Potato plots were sidedressed with granular formulations of diazinon at 2.8 lb./acre, parathion at 3.5 lb./acre, disulfoton at 4 lb./acre, or phorate at 3.3 lb./acre on May 3, 1965. Residues in the tubers were below the limits of sensitivity of the analytical method at harvest.

2. Chlordane Residues in Potatoes. Potato plots planted May 10 were sidedressed on June 4, 1965, with chlordane emulsifiable concentrate at the rate of 3 lb./acre. The residues in the tubers harvested on September 28 ranged from less than 0.01 to 0.13 ppm of chlordane. The average residue of 3 plots was 0.05 ppm.

3. Malathion Residues in Potatoes. Aerial sprays of undiluted technical (LV) and conventional dilutions of malathion (10 gal./acre), each at 12 ounces actual per acre, were applied to potatoes. The initial malathion residues on potato leaves from the dilute and LV sprays were 45.4 and 103.7 ppm, respectively; after 14 days these residues had decreased to 0.64 and 5.90 ppm.

4. Persistence of Organophosphorous Materials in Soils. At Yakima 8 granular formulations and 1 emulsifiable concentrate formulation of

organophosphorous insecticides were mixed with samples of virgin Sagemoor loam soil and subjected to weathering over a period of 8 weeks. Treated soil samples were bioassayed against wireworms and soils showing toxicity were analyzed for insecticide. The amounts of insecticide found in the soil initially and after 8 weeks were as follows: Granular parathion, 5.3 and 0.31 ppm; buffered granular parathion, 1.1 and 0.9 ppm; parathion emulsifiable concentrate, 1.1 and 0.8 ppm; granular Zinophos, 0.20 and 0.01 ppm (test period only 4 weeks); granular Stauffer N-2790, 0.27 and 0.08 ppm; granular Bay 37289, 0.66 and 0.49 ppm; granular Niagara NIA-10242, 2.7 and 0.72 ppm; granular Bay 25141, 2.5 and 1.7 ppm (test period only 6 weeks); and granular diazinon, 1.7 and 0.40 ppm.

5. Insecticide Content of Wireworm Larvae. At Yakima wireworm larvae contained 7.6 and 21 ppm of aldrin plus dieldrin, respectively, after exposure for 9 days to soils containing 1.25 and 2.50 ppm of aldrin. Analyses of larvae from the 7.6 ppm lot after exposure to insecticide-free soil for 7, 14, and 28 days indicated decreases to 4.0, 4.2, and 0.61 ppm of aldrin plus dieldrin, respectively. Analyses of larvae from the 21 ppm lot likewise exposed to insecticide-free soil indicated decreases to 18, 9.6, and 8.2 ppm. Analysis of the previously insecticide-free soil after the larvae had been kept in it showed 0.009 ppm of aldrin plus dieldrin.

D. Biological Control

1. Aphids. At Yakima, Wash., 6 kinds of syrphid flies were found preying on aphids on peach trees in the autumn of 1965. Syrphid larval activity was found on over half of the aphid-infested leaves; however, maximum stimulation for syrphid egg deposition was approximately 30-40 aphids per leaf.

The possibility of eliminating or markedly reducing populations of the green peach aphid and spread of leaf roll in potatoes by eradicating Canada plum, the primary host of the aphid, is being investigated at Presque Isle, Maine. Aphid population trends on untreated potatoes in isolated test areas of about 120 and 20 square miles are being studied. Canada plum in the 120-square-mile area will be destroyed with herbicides in 1966 and determinations of the compositions and trends of aphid populations will be made on potatoes in the test and check areas in 1967.

Parasitism of potato-infesting aphids on potatoes at Presque Isle was about the same level in 1965 as in 1964. Parasites reared from aphids on potatoes in 1964 showed that 39 percent of the primary parasites were parasitized by hyperparasites, an increase of 3 times as compared to 1962 data.

Coccinellid and syrphid aphid predators were slightly less abundant in 1965 than 1964 but spiders and chrysopids were more abundant. The coccinellids were 62% 13-spotted lady beetle, 18% transverse lady beetle, and 16% miscellaneous species. In former years the 13-spotted lady beetle has been present in trace numbers only.

Entomogenous fungi were found at Presque Isle slightly later in 1965 than in 1964, but the peak of abundance of dead diseased aphids came earlier and the epizootic was more complete in 1965. The effect of the fungi upon rate of aphid population growth was not apparent during the first 2 weeks after first occurrence but increased sharply thereafter. The delay in effect on aphid increase may be due to the shift in prevalence of the two most common species of fungi. Entomophthora aphidis was the most prevalent species initially but after 2 weeks E. thaxteriana became the predominant one. E. aphidis formerly was considered the more pathogenic; however, infections of E. thaxteriana may also affect the rate of aphid population growth. For the first time, in 1965 Entomophthora obscura was recovered from a dead diseased aphid on potatoes. Identification was made by I. Hall and J. Bell at Riverside, Calif.

Evidence obtained at Presque Isle in 1965 indicates that control of aphids on potatoes by natural agents is influenced by the size and border separations of the plantings. Aphid populations were larger and the seasonal peak was later in small fields of potatoes than in nearby small plots separated by oats or by bare fallow where diseased aphids appeared earlier. Parasitized aphids were more common in potatoes surrounded by oats than by bare fallow or in the small fields.

Entomogenous fungi appear to exert better aphid control in plots planted to potatoes every second year and surrounded by oats than in fields planted wholly to potatoes.

At Presque Isle, Maine, in 1965 in small plots and fields the results of studies to determine the effect on aphid potato populations of sustained releases of Coccinella septempunctata eggs or larvae or Chrysopa spp. larvae were masked by predator movement between plots so that treatment differences were not statistically significant. Oat- and aluminum-on-edge (in bare fallow land) plot separations prevented interplot movement of the aphids, but did not confine introduced predators.

In field cages and fields potato aphids became the dominant species where chrysopids were introduced, and the green peach aphid became dominant where the coccinellids were introduced.

The introduced predator Coccinella septempunctata L. overwintered as well in field cages over grassland in 1965-66 as in 1964-65, and in 1965-66 as well or better where no protection such as grassland inside the cages covered with several layers of burlap topped with a plastic cover was added.

Mass production techniques for parasites and predators of potato-infesting aphids are being studied under a cooperative agreement with the Maine Agricultural Experiment Station. As many as 3,000 C. septempunctata larvae per week were produced. Information on development under different environmental conditions now appears adequate for initiation of a mass-production program.

Experience in egg production indicated the need for methods to prevent or break diapause in beetles that overwinter in field cages at Presque Isle. Studies are underway with two parasites (1) Aphidius matricariae and (2) Praon spp. Thus far oviposition by these parasites has not been obtained.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Aphids. At Yakima, Wash., 8,761 peach trees were located and sprayed in April with a 275-mi.^{2} control area upwind from the potato district. The program is designed to control the green peach aphid carrier of leaf roll disease and reduce spread of this disease in eastern Washington. The green peach aphid overwinters in the egg stage on peach trees. Aphids from colonies that develop after the eggs hatch move to potato fields. Estimates suggest the peach trees may contain 10,000 eggs per tree. Bi-weekly examinations of 60 aphid traps placed 4 miles apart downwind from the control area in May and June showed the area control program had delayed the spring flight of the aphids at least 6 weeks.

F. Evaluation of Equipment for Insect Detection and Control

1. Thrips and Mites. At Yakima, Wash., a counting board for use in detecting and evaluating populations of thrips and mites in the field was developed. It consists of a 9-square-inch piece of cotton filter cloth placed on a clipboard. The board is slipped under potato plant foliage. The plant is then struck 5 times with the hand. The method is useful for studying thrips populations and proved as accurate and much quicker for estimating mite populations than a mite brushing machine.

G. Varietal Evaluation for Insect Control

1. Aphids. At Presque Isle a study of 5 varieties of potatoes as breeding hosts of aphids indicated that Chippewa is a better host of potato or green peach aphids than Katahdins. Kennebec was a better host and Russet Burbank a poorer host than Katahdins for the buckthorn aphid. Chippewa was the only variety having a total-season aphid population larger than that on Katahdin.

H. Insect Vectors of Diseases

1. Aphids. In 1965 at Presque Isle as high as 90% control of leaf roll spread was obtained in plots where 10% of the potato stands were leaf roll reservoirs and green peach aphids were introduced to provide infestation. The plants were sprayed with 1/4% or 1/2% solution of chlorocholine chloride at 125 gal./acre of the spray mixture. Best control was obtained where the plants were colonized with aphids 1 week after the second of 2-weekly spray applications, and least control was where colonization occurred 1 week before spraying. There was little difference because of strength of the chlorocholine chloride in the spray. Most of the spread of leaf roll occurred during the first week after colonizing the plants with the green peach aphid.

Preliminary greenhouse studies indicated approximately 60% control of field spread of potato virus-Y after 3 or 6 applications of 2 gal./acre oil spray over a 6-week period to potato plants in replicated small plots. Stands of plants contained 5% disease plant reservoirs and were colonized with green peach aphids.

Aphid control in Katahdin and Chippewa potato, with 3% leaf roll reservoir plants, reduced the spread of disease to 1/16th of the spread where aphids were not controlled. Disease spread in untreated Chippewas was about 2 times as much as in untreated Katahdins, but only $1\frac{1}{2}$ and 3 times that of reservoir plant abundance in Katahdin and Chippewa plantings, respectively. Near-perfect control of aphids and leaf roll spread followed a planting furrow application of disulfoton at 1 lb./acre.

At Simla (Punjab), India (PL480 Project A7-ENT-33), a study was initiated July 1, 1965, to detect and measure hereditary variation in the ability of the green peach aphid to transmit the potato leaf roll and Y viruses. Initially, emphasis was upon establishment of strains or pure lines of the aphid for use in the transmission studies. Six pure lines of the aphid were established and preliminary tests of virus Y transmission initiated.

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Insect Vectors of Diseases

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PUBLICATIONS -- STATE EXPERIMENT STATIONS AND COOPERATIVE PROGRAMS

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Insect Vectors of Diseases

Bishop, Guy W. 1965. Green peach aphid distribution and potato leaf roll virus occurrence in the seed producing areas of Idaho. J. Econ. Entomol. 58: 150-3.

AREA NO. 3. DECIDUOUS FRUIT, TREE NUT, GRAPE, AND BERRY INSECTS

Problem. Insects and mites are important limiting factors in production of high quality fruits, nuts, grapes, and berries, shortening the profitable life of the trees, vines, or plants, and reducing the yield or quality of the crop. Certain insects and mites transmit diseases that adversely affect the life and productivity of the host plant. No one method of control is fully satisfactory and methods that are effective now may not be so later. At present biological, cultural, and other nonchemical methods of control are available for comparatively few insect pests. Much dependence is placed on insecticides for control. The continued use of insecticides, however, is complicated by the occurrence of insecticide-resistant strains of an increasing number of insects and mites, by the need to avoid objectionable residues on fruits and berries and on their waste products used for livestock feed, by their detrimental effects on beneficial insects, fish, and wildlife, and by contamination of non-target areas. There is a continuing need for research to develop more selective, economical, and safer insecticides; and for intensified research on alternate types of control such as those based on the use of attractants, repellents, traps, insect-resistant varieties and materials that affect insect growth and reproduction, including chemosterilants. More research is needed on integrated chemical-biological control programs with less intensive insecticide usage, so that the maximum benefits from parasites, predators, and pathogens may be realized. Research is required to determine more fully the role of insects in the transmission of important diseases affecting the production of these crops, and to determine host preferences, distribution, and habits of the insect vectors, and method of population suppression. Means must then be developed to reduce or eliminate the vector populations responsible for spread of the diseases.

USDA AND COOPERATIVE PROGRAM

The Department has a long-term program involving entomologists, chemists, insect physiologists, and insect pathologists engaged in both basic studies and practical solution of growers' problems. Research on pome and stone fruit insects is carried on at Yakima and Wenatchee, Wash., Vincennes, Ind., Wooster, Ohio, Kearneysville, W. Va., and Fort Valley, Ga., in cooperation with the respective State Experiment Stations. Research on insects and mites affecting pecan production is carried on at Albany, Ga., and Shreveport, La.; on insects affecting the production of grape, blueberry, and black walnut at Wooster, Ohio, in cooperation with the Ohio Experiment Station; and on strawberry insects at Beltsville, Md. Research on insects and mites in relation to the transmission of diseases of deciduous tree fruits is carried on at Riverside, Calif., Corvallis, Oreg., Wenatchee, Wash., and Fort Valley, Ga., in cooperation with the respective State experiment stations and the Crops Research Division. Work is also being

conducted under grants at the Washington, North Carolina, California, and Colorado Agricultural Experiment Stations, and at Brigham Young University in Utah.

The Federal scientific effort devoted to research in this area totals 19.5 professional man-years. Of this number 3.8 is devoted to basic biology and nutrition; 4.7 to insecticidal control; 1.9 to insecticide residue determinations; 1.3 to biological control; 4.9 to insect sterility, attractants, and other new approaches to control; 0.4 to evaluation of equipment for insect detection and control; 1.3 to insect vectors of plant virus diseases; and 1.2 to program leadership.

In addition Federal support under grants provides for a total of 4.8 professional man-years of research in this area. Of this total 2.0 is devoted to basic biology, physiology, and nutrition, 2.6 to insect sterility and attractants, and 0.2 to varietal resistance.

Research under grants of PL 480 funds (Projects E21-ENT-2 and 5) to the Institute of Pomology, Skierniewice, Poland, for studies of the differences in susceptibility and in cholinesterases in various species of spider mites, as influenced by acaricides and for studies on the biological control of mites, aphids, and scale insects on deciduous tree fruits and effects of pesticides on natural enemies has been completed. Studies are in progress by the Institute of Pomology, under PL 480 (Project E21-ENT-8) to study the mite fauna in Poland orchards with special reference to the relation between phytophagous and predaceous species. A portion of a grant of PL 480 funds (Project A17-ENT-5) to the Commonwealth Institute of Biological Control, Rawalpindi, Pakistan, for research on scale insects, fruit flies, and mites, and their natural enemies in West Pakistan is applicable to insects affecting deciduous tree fruits.

PL 480 projects recently initiated were: Israel (A10-ENT-13) on factors influencing variations in insecticide resistance, including resistance of codling moth to insecticides; Poland (E21-ENT-16) on population trends of predaceous arthropods in apple orchards sprayed with pesticides and the influence of these trends on population density of phytophagous mites and other pests; and Yugoslavia (E30-ENT-2) on leaf miners in orchards.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 50.2 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Codling Moth. This insect is being sucessfully reared in large trays on an artificial diet at Yakima, Wash. Cannabalism proved to be density-dependent and could be regulated somewhat, thus obviating the necessity of

rearing the larvae in individual containers. Desiccation, the most troublesome aspect of rearing in large trays, was corrected by applying a thin coat of paraffin to the surface of the medium. Addition of sorbic acid and methyl p-hydroxybenzoate to the diet generally controlled fungus contaminants. Production costs are now estimated at $4.80/1000. Facilities are being completed which will increase production to 2000/day.

Immersion of codling moth pupae in a 1 molar reagent grade of Cupriethylene diamine for 45-60 minutes was an effective treatment for mass removal of the silken cocoons without causing adverse effects on the insects. Shorter and longer immersion periods resulted in unsatisfactory cocoon dissolution and excessive mortalities, respectively.

Studies at Pullman, Wash., under a research grant revealed that the critical photoperiod for diapause of the Washington strain (47° N) is longer (14.5 to 16 hours) than that previously shown in California (34° N, 12 to 15 hours). A circadian oviposition rhythm is present, with peak oviposition occurring 3 hours prior to termination of the photophase.

2. Peach Tree Borers. At Vincennes, Ind., lesser peach tree borer adults would not mate or oviposit readily under artificial conditions because of their sensitivity to physical factors and disturbances. A special mating chamber was prepared to provide adequate natural lighting and supplemental artificial lighting for use on cloudy days with slow moving air heated to a constant 85° F being drawn into the chamber. Techniques have been developed to increase laboratory production of lesser peach tree borer on green thinning apples to about 7000 adults per month.

Emergence of peach tree borer moths varied from shortly before 8:00 a.m. until shortly after noon at Fort Valley, Ga. The mean times of emergence for 375 males and 381 females were 9:04 and 9:14 a.m., respectively. Adult female peach tree borers began emitting sex pheromone at an average time of 12:05 p.m. on the day of emergence. On subsequent days they began at an average time of 11:13 a.m. The females were most attractive to males on their second and third days of adulthood.

Research under a grant at North Carolina State University showed that peach tree borers could be reared on green thinning apples sufficiently well to provide larvae for testing synthetic diets. Larvae are developing well on one of the synthetic diets. Until a colony can be maintained year round, it will be necessary to obtain field-collected larvae for testing.

3. Plum Curculio. At Fort Valley, Ga., non-diapause plum curculio females that had mated in the fall produced as many larvae the following spring when held without males as those held constantly with males. Since the Central Georgia strain of plum curculio is largely non-diapausing and presumably carries large amounts of viable sperm overwinter, indications are that in a sterile male release program it would be necessary to compete with viable sperms already present in the females from the previous season's matings in addition to competing with normal males in the natural population.

Improvements in techniques for rearing plum curculio in Georgia have increased production to over 10,000 larvae per bushel of green thinning apples at a cost of about $2.50 per bushel for the apples.

4. Pecan Insects. A study of the reproductive systems of the female hickory shuckworm moth at Albany, Ga., showed that in mated females the bursa copulatrix is enlarged and hardened; in unmated females it is flattened, opaque, and slightly folded near the center. Whether the moth has mated can be determined rapidly by grasping the vulva with forceps and pulling the bursa copulatrix out through the body wall.

During 5 days of confinement 24 of 58 female hickory shuckworm moths obtained from overwintering larvae collected in the fall and refrigerated at 32° F mated successfully. Male shuckworms mated more than once. Female moths preferred pecan leaves for oviposition rather than ridged plastic, paper, and tape.

In preliminary studies to develop an artificial diet for rearing hickory shuckworm, a diet containing ground sprouted pecans, soybean protein, Brewer's yeast, granulated sugar, Wesson salts, cholesterol, vitamin mixture (NBC), agar, and ascorbic acid appeared the most promising of six tested.

5. Insect Vectors of Virus Diseases. At Riverside, Calif., 13 species of eriophyid mites in orchard plant associations, 3 of which are important on pear or apple, and 2 from related pomaceous hosts, were named and described. The most significant of these, Eriophyes pseudoinsidiosus Wilson, an economic species which produces blisters on pear leaves, has obviously been present over a wide range for some time but never before taxonomically separated from the pear leaf blister mite, Eriophyes pyri.

Studies in California showed that incidence of diapause and body form of the adult pear psylla is governed by photoperiod. Diapause is induced particularly by the photoperiods experienced by the last 2 nymphal instars, but production of winter-forms is influenced by the photoperiod in earlier instars.

The minimum effective light intensity was approximately 0.2 foot candles, an intensity encountered somewhat before sunrise and after sunset. At 80° F, with cage-reared populations of pear psyllas from central and southern California, diapause was induced at about 14 or less hours of light per day for each strain.

At Wenatchee, Wash., in research under a grant, the sex ratio of pear psylla caught in a rotary net did not vary significantly from 1:1 throughout the season. Multiple mating is required for maximum egg laying. Preliminary observations indicate that overwintering adult psylla will mate in the fall but will not oviposit during photoperiods of 10 hours or less. Ovarian diapause is terminated by lengthening the photoperiod to 14 hours even though the adults have not been exposed to temperatures below 65° F.

6. Miscellaneous Insects of Deciduous Fruits. At Provo, Utah, in research under grant, collection of approximately 3,000 mites over a 6-month period indicated about 30 species inhabiting the trees and about 48 in the cover and soil beneath the trees.

At Wooster, Ohio, early larval instars of elder shoot borer, transferred from the host plant to artificial food media of the European corn borer, were reared to adults.

Laboratory rearing of the egg parasite, Trichogramma minutum, was increased to approximately 10,000 parasites per week with improved techniques at Vincennes, Ind. Increasing relative humidity within rearing chambers to 70-85%, at temperatures of 70-82° F, enhanced survival of immature Trichogramma to the extent that the percent emergence of adult parasites from codling moth eggs was increased from 40 to 78.

B. Insecticidal and Cultural Control

1. Codling Moth. Codling moth was adequately controlled on apples by three applications of azinphosmethyl and one application of carbaryl in field tests at Kearneysville, W. Va.

2. Orchard Mites. At Wenatchee, Wash., there was evidence that McDaniel mites may have developed resistance to binapacryl. Laboratory bioassays of mites from an orchard with a history of treatment with binapacryl gave 17% mortality at a dosage equivalent to 0.5 pound actual per 100 gallons. Mortality of mites from an orchard with no binapacryl history was 92% at a dosage of only 0.03 pound actual per 100 gallons.

In laboratory screening tests at Yakima, Wash., two experimental materials gave 100% and 93% control, respectively, of two-spotted spider mites 3 days after application. In orchard tests four experimental materials were effective against McDaniel mites and three against European red mites.

Airplane applications of undiluted technical malathion (LV) to apple orchard plots reduced the population of McDaniel mites to one-third of that in another plot where a conventional air application of dilute malathion (10 gal/acre) was made. Both applications provided 4 pounds actual toxicant per acre. Within 10 days the mite populations in both plots doubled, whereas there was a slight decrease in population during the same period in a third plot sprayed with Kelthane.

In laboratory tests at Vincennes, Ind., both foliar and systemic applications of Ortho-9006 controlled two-spotted spider mites on lima beans. Foliar sprays of Mobil MC-327 also gave excellent control.

Studies in Poland (PL 480 project E21-ENT-5) showed that two spray applications in one season reduced to low numbers the orchard mites, Bryobia rubrioculus and Panonychus ulmi. Extremely cold winter temperatures

greatly reduced the overwintering stages. Late spring freezes also reduced populations and the need for spraying. Clean culture in an orchard growing on Festuca sod had no effect on Bryobia mite populations.

In other studies conducted in Poland (PL 480 project E21-ENT-2) dormant tar wash sprays applied in late autumn were less deleterious to scale predators than late spring treatments with the same material.

3. Pecan Insects. At Albany, Ga., 3 or 5 applications of parathion at 0.3 pound actual per 100 gallons were inferior to the standard treatment of 3 applications of EPN at 0.5 pound actual per 100 gallons for control of hickory shuckworm on Farley pecans. Five applications of parathion were no better than 3 applications. Three or 5 applications or malathion at 0.75 pound actual per 100 gallons were less effective than the parathion treatments.

Triphenyl tin hydroxide and carbaryl applied as 4x concentrate sprays at the respective rates of 1.6 and 4 pounds actual toxicant per 100 gallons on large pecan trees of the Schley variety controlled pecan weevil infestations with no detectable difference in their effectiveness.

Triphenyl tin hydroxide at 0.1 or 0.2 pound actual per 100 gallons applied to pecan trees of the Farley variety gave 95% control of the nut casebearer, whereas the standard, parathion, applied at 0.3 pound gave almost complete control.

At Shreveport, La., azinphosmethyl applied with an air blast ground sprayer gave almost complete control of the mite, Oligonychus viridis. Undiluted technical malathion (LV) applied by air at the rate of one pound per acre was ineffective.

Aerial applications of undiluted azinphosmethyl EC at the rate of 0.5 pound actual per acre, or conventional dilutions of azinphosmethyl at 1 pound actual in 6 gallons of water per acre were evaluated for control of nut casebearer. Nut cluster infestations that developed were as follows: Conventional dilute spray 5%, LV spray 14.5%, and the untreated check 20.5%.

Methyl demeton painted on the trunks of 5 year old pecan trees reduced infestations of yellow aphids to 0.24 aphids per leaflet, compared to 3.3 aphids per leaflet on untreated trees 2 weeks after treatment.

An aerial application of parathion at 1 pound actual in 20 gallons of water per acre effectively controlled the black pecan aphid.

4. Miscellaneous Insect Pests of Deciduous Fruits. In orchard tests against pear psylla at Yakima, Wash., Imidan was as effective as Perthane EC, the standard. Three superior type oils of 57, 60, and 140 viscosities were somewhat less effective than Perthane but held the psylla population below injurious numbers throughout the season.

Airplane applications of undiluted technical Perthane to Bartlett pears as a prebloom spray gave excellent control of pear psylla. Similar applications of malathion and azinphosmethyl failed to give adequate control.

Temik 10% granular, broadcast over the root area of 10-inch diameter pear trees at 1, 2, and 3 ounces per inch diameter of tree trunk, controlled pear psylla as effectively as sprays of Perthane.

At Fort Valley, Ga., several insecticides applied in combination with 2% superior oil before leaf fall or with 3% dormant oil during November and December failed to give adequate control of adult white peach scales. The best control, 60-70%, was achieved with parathion or azinphosmethyl combinations.

Matacil and endosulfan give outstanding control of the lesser peach tree borer and were significantly better than DDT plus parathion at Kearneysville, W. Va.

At Wooster, Ohio, 3 spray applications of carbaryl plus malathion gave excellent control of a blueberry tip borer when sprays were properly timed and properly applied.

Bait sprays of vegetable protein hydrolysate and malathion gave acceptable control of apple maggot and blueberry maggot in Ohio when sprays were started early, intervals between sprays were not too long, spray mixtures were at the proper concentration, and properly applied.

Carbaryl sprays in 2 applications gave satisfactory control of eriophyid mites on butternut trees. Timing of the first spray was important.

Properly timed sprays of carbaryl, lindane or delayed dormant oil sprays gave acceptable control of the hickory gall aphid.

C. Insecticide Residue Determinations

1. Codling Moth. At Yakima, Wash., aerial sprays of undiluted technical (LV) malathion at 4 pounds actual toxicant per acre left initial residues on apple and pear leaves 1.3 and 1.4 times higher, respectively, than the conventional dilutions. After 14 days the apple and pear leaves had lost 86.0 and 78.1%, respectively, of the initial residues from the low volume treatment, while the loss from the dilute sprays was 90.7 and 97.7%. There was no significant difference between the drift characteristics of the two formulations. Thirty percent of the malathion applied by the low volume technique reached the ground compared with 24% of that applied in water.

Granular Temik broadcast on the soil surface under pear trees at 0.1 pound actual toxicant per tree and washed into the soil with 25 gallons of water resulted in no residues in leaves or twigs up to 145 days after treatment except in one leaf sample taken 56 days after application. This sample

contained 0.15 ppm of residue. Soil samples contained residues of 7.22 ppm at the time of application and 0.63 ppm 91 days later. Soil taken 163 days after the application and pears sampled at harvest time, 125 days after the treatment, contained no detectable residues.

D. Biological Control

1. Codling Moth. Eggs produced by normal female codling moths mated with males treated with 42 kr of gamma radiation were about 98% sterile. When eggs from such a mating were exposed to adults of the egg parasite, Trichogramma minutum, 84% of the eggs sustained an F_1 generation of T. minutum. In a comparable test in these studies at Yakima, Wash., 95% of the eggs from normal parents sustained an F_1 generation of the parasite.

2. Peach Borers. During the spring and early summer more than 10,000 lesser peach tree borers and over 450 American plum borers emerging from about 16 cords of heavily infested peach wood placed in screened cages were collected at Vincennes, Ind. The American plum borers were used to start a laboratory culture. Ninety-three braconid and 54 ichneumonid parasites were also collected. In parasite-host exposure chambers several successful parasitizations of the two boring insects occurred. Seven females and 1 male of Devorgilla sp. and 1 female Pimpla annulipes, both ichneumonid wasps, were reared from egg to adult stage under laboratory conditions. The former species was reared on larvae of the American plum borer, while the latter's host was a lesser peach tree borer larva.

When placed in a rearing chamber with approximately 1,000 Trichogramma minutum adults, 83 of 121 eggs of the American plum borer were parasitized and 123 T. minutum emerged -- an average of about 1.5 parasites per parasitized egg.

3. Red Banded Leaf Roller. At Vincennes, Ind., a laboratory population of Trichogramma minutum which has been maintained on codling moth eggs is now also being reared continuously on red-banded leaf roller eggs. Trichogramma is known to parasitize the genus Argyrotaenia but no records have been found to indicate that it parasitized the red banded leaf roller, species A. velutinana.

Weekly field applications of Thuricide TS, a flowable formulation of the pathogen Bacillus thuringiensis, at dosages of 2, 4, 8, or 16 ounces of formulation per tree, reduced the percent survival of red-banded leaf roller larvae. The reductions ranged from 25% at the 2-ounce dosage to 69% at 16 ounces.

4. Miscellaneous Insects of Deciduous Fruits. In studies of predaceous mites in Poland (PL 480 project E21-ENT-8), phytoseiid mites in deciduous fruit orchards were greatly reduced when prolonged rains were followed by low winter temperatures. Similar mortalities of mites were obtained at low temperatures in laboratory experiments.

Typhlodromus findlandicus mites brought into the laboratory from hibernation fed on eggs and nymphs of Tetranychus urticae with no apparent preference but favored tarsonemid mites less for food. This predaceous mite laid fewer eggs and had a shorter life span if removed from hibernation before normal emergence in May.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Codling Moth. A pilot test was started in 1966 at Yakima, Wash., to determine the usefulness of releases of sterile codling moths as a method for commercial control of this important pest of apples. The moths are sterilized by treatment with the chemosterilant tepa, or by gamma radiation, and released in a 15-acre apple orchard at a ratio of about 400 sterile to 1 wild male moth. The test orchard is located within an intensively cultivated apple-growing area in which normal spray operations conducted for control of codling moth provide a minimum of opportunity for large-scale influx of wild moths into the test block.

In trapping studies in Washington to determine dispersal of codling moths, 26 native and 5 sterile moths were captured in a single trap 1 mile from an apple orchard where sterile male moths were being released, and 107 native and 28 sterile moths were captured in 3 traps $\frac{1}{2}$ mile from the release orchard. No other orchards were located within 1 mile of these traps, indicating that dispersal of codling moths may be greater than generally believed.

In other tests within a release orchard during late summer, nearly 5 times as many moths were captured in traps hung 10 feet above ground level as in traps hung at 4 feet.

Codling moth catches in blacklight traps and traps baited with virgin females were not significantly different. The seasonal mean daily catch of native moths was 1.8 per light trap and 2.0 per sex attractant trap. Combination light and sex attractant traps did not enhance codling moth catches as has been the case with certain other lepidopterous insects. In an orchard involving releases of sterile males, the mean daily catch of released plus native moths between June 23-July 6, in sex attractant traps was 29.9 males/trap and that in the combination light-sex attractant traps was 30.5 males/trap. Sex attractant trap catches exceeded those in other traps when the weather was cool but light trap catches were highest in hot weather.

2. Peach Tree Borers. At Vincennes, Ind., a novel experiment was started to determine the feasibility of suppressing populations of lesser peach tree borers by trapping males in sticky traps baited with virgin female moths. Sixty traps, each baited with 2 virgin females which were replaced on alternate days, were distributed in a 45-acre (3488 trees) peach orchard, considered to be almost free of borer infestation. The orchard was at least 5 miles from the nearest commercial peach orchards but the buffer zone

surrounding the test orchard contained approximately 700 backyard trees and an undetermined number of wild host trees. By late spring a total of 1457 male lesser peach tree borers were trapped. No female moths were trapped and no infestations had developed in the test orchard as of July 1.

Filtrates and extracts of whole bodies and of excised abdominal tips of virgin female lesser peach tree borers placed in acetone were attractive to males when bioassayed in 7.5 ft^3 outdoor screen cages in Indiana. When sticky traps were baited with equivalents of each material and placed in cages with 200 males, as high as 66.5% of the males were captured. Males responded to both filtrates and extracts but those prepared from whole females elicited the greatest response. Most of the males were caught during the first 20 minutes, but the filtrate remained potent for about $2\frac{1}{2}$ hours. Stock materials were potent when exposed after storage of at least 48 hours.

In preliminary trapping studies at Fort Valley, Ga., 35 male peach tree borers were caught by 5 sticky traps baited with 2 or 3 virgin females. Approximately 2/3 of all males that investigated the traps were caught.

3. Pear Psylla. Adult male pear psyllas were sterilized when caged in the laboratory on pear foliage that had been dipped in a 3% solution of tepa and then dried at Riverside, Calif. After exposure to treated foliage for as long as 22 hours, the males mated readily with normal virgin females. Twenty-nine of 31 females mated to treated males laid infertile eggs; the infertile lots included 654 eggs. In the 2 instances when the males were not completely sterilized, 63 eggs were laid, of which 19% hatched.

Blacklight, blacklight B (visible light filtered), green, and white light were attractive to adults of the pear psylla in preliminary laboratory experiments at Riverside, Calif. In more than 100 tests involving groups of 10 insects per test introduced into a darkened chamber with the test-light source at one end, the lights attracted 37 to 67% of the psyllas placed in the chamber. When the insects were furnished choices between 2 colors, the blacklight was the most attractive. Red and yellow lights were not attractive.

4. Pecan Insects. Acetone extracts of female pecan nut casebearer and female pecan leaf casebearer moths failed to attract male moths to sticky board traps in pecan orchards in Georgia.

5. Miscellaneous Insect Pests of Deciduous Fruits. In blacklight trapping studies under a grant at Grand Junction, Colo., male and female oriental fruit moths were trapped in nearly equal numbers. Of 1409 females captured, 4.3% had not mated, 89.9% had mated once, 5.0% had mated twice, 0.78% had mated 3 times, and 0.07% had mated 4 times. A laboratory culture of the oriental fruit moth was established from a local peach source, but rearing problems have prevented a large increase in this culture.

In studies at Berkeley, Calif., under a research grant, males of the navel orangeworm were attracted to the female moths. Females 0-1 day old were the most attractive. A methylene chloride extract of female abdominal tips elicited some male response. Irradiation of pupae at a dosage of 60 kr resulted in approximately 99% non viable eggs. Optimum dosage for adult sterilization was 40-50 kr.

At Wooster, Ohio, yellow-colored sticky board traps were more satisfactory in trapping apple maggot or walnut husk maggot adults than colors ranging from orange to red. Sticky board traps, baited with 3 types of vegetable protein hydrolysates as well as with ammonium carbonate, gave no significant differences in the catch of adult flies of the walnut husk maggot.

I. Insect Vectors of Diseases

1. Pear Decline. Additional positive readings in vector tests with pear decline disease in California added substantially to the concept that pear decline is caused by a virus and is transmitted by the pear psylla.

Workers in other agencies in California recently described a disorder termed pear leaf curl, a disease of unknown cause but found in association with pear decline and threatening losses possibly greater than those resulting from pear decline. The symptoms thus far determined consist of a downward curling of leaves and purplish coloration of foliage. They appear only during a few weeks just prior to autumn leaf drop. Fruit yield of affected trees reportedly may be reduced by as much as 80%. Pear leaf curl affects trees of all rootstocks observed, whereas pear decline affects mostly trees on oriental rootstock.

In vector tests with pear decline inoculum and pear psylla at Riverside, at least 10 cases on recipient trees were diagnosed as pear leaf curl rather than the expected pear decline; check trees remained normal. Further tests under closely controlled conditions will be required to substantiate this development.

2. Miscellaneous Stone Fruit Virus Diseases. In further cooperative studies of a new, damaging, rapidly spreading virus of cherry at Corvallis, Oreg., virus obtained from infected sweet cherry reacted with cucumber mosaic antiserum, indicating that this virus is a strain of cucumber mosaic virus; this hypothesis is supported by the aphid transmission, with a lack of vector specificity. The virus has now been transmitted by 10 species of aphids including Acyrthosiphon pisum (Harris), Aphis craccivora Koch, Aphis pomi DeGeer, Brachycaudus cardui (L), Macrosiphum californicum Clarke, Macrosiphum rosae (L), Myzus cerasi (F.), Myzus lythri (Schrank), Myzus persicae (Sulz.), and Pentatrichopus sp.

The virus was retained less than 1 hour by feeding aphids.

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AREA NO. 4. CITRUS AND SUBTROPICAL FRUIT INSECTS

Problem. Insects and mites that attack citrus and subtropical fruits reduce yield, lower quality, spread plant diseases, contaminate the marketable product, and increase cost of production. There is a continuing need for research to secure biological and ecological information on these pests that will provide a better basis for the development and implementation of insect control methods than that now available, or suggest additional non-chemical approaches to their control. Additional research is needed on biological control agents, including parasites, predators, and pathogens, and on methods for more effectively integrating biological, chemical, and other control measures. Safer, even more effective and economical control procedures that will minimize or avoid objectionable chemical residues and problems associated with residues should be developed. Research on attractants, chemosterilants, sterilization techniques, and genetic methods need increased attention. Protection against introduction into the United States of tropical fruit flies or other foreign injurious insect species requires effective low-cost detection methods, processes for destroying insect infestation in fresh fruits and vegetables intended for shipment to uninfested areas and eradication procedures for use in emergency situations to eliminate incipient insect infestations.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program involving both basic and applied research on insects and mites infesting citrus and subtropical fruits and on treatments for control of insects and related pests in commodities regulated by plant quarantines. This program is carried on at Beltsville, Md., Honolulu and Hilo, Hawaii, Riverside, Calif., Orlando, Fla., and Weslaco, Tex., in cooperation with entomologists, chemists, and agronomists of the respective State Experiment Stations; also at Orlando, Fla., in cooperation with the Crops Research and Plant Pest Control Divisions; at Hoboken, N.J., in cooperation with the Plant Quarantine Division; at Mexico City, Mex., in cooperation with the Plant Pest Control Division and with the Direccion General de Sanidad Vegetal of the Mexican Secretaria de Agricultura y Ganaderia, and on the islands of Guam and Rota in cooperation with the Territory of Guam, U.S. Navy, and the Trust Territory of the Pacific Islands. Work initiated in 1964 in San Jose, Costa Rica, on the Mediterranean fruit fly with funds supplied by the Agency for International Development (AID) in cooperation with the Organismo Internacional Regional de Sanidad Agropecuaria (OIRSA), and with the Interamerican Institute for Agricultural Sciences at Turrialba, Costa Rica, was terminated at the close of 1965.

The Federal scientific effort devoted to research in this area totals 22.3 scientist man-years. Of this number, 3.6 is devoted to basic biology, physiology, and nutrition; 2.2 to insecticidal control; 0.4 to insecticide residue determination; 3.0 to biological control; 7.6 to insect sterility,

attractants, and other new approaches to control; 3.4 to insect control treatments for commodities regulated by plant quarantines; 0.1 to varietal evaluation of insect resistance; 0.7 to insect vectors of diseases; and 1.3 to program leadership.

In addition, Federal support of research in this area under grants and cooperative agreements totals 0.4 man years. Of this total 0.1 is devoted to biological control and 0.3 to insect attractants.

PL 480 research grants include India (A7-ENT-26), Biology of gall midges affecting mangoes with special reference to extent of damage; India (A7-ENT-35), Biology of gall midges affecting citrus plants with special reference to the extent of damage; Pakistan (A17-ENT-5), Studies on scale insects, fruit flies, and mites and their natural enemies in West Pakistan; Greece (E11-ENT-1), Control of the olive fly with radiation or chemical sterilization procedures; Egypt (F4-ENT-3), Induced sterility in males of Mediterrean fruit fly as a means of controlling and eradicating that pest.

New PL 480 projects recently initiated include grants for research in India (A7-ENT-47) on biology of gall midges affecting figs with special reference to the extent of damage; and in Israel (A10-ENT-13) on factors influencing variations in insecticide resistance, and (A10-ENT-15) on the ecology, biology, and control of the citrus bud mite (Aceria sheldoni, Eriophyidae).

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 28.9 professional man-years is devoted to this area of research.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Citrus Insects and Mites. California red scale males in free flight within an 8 x 12 x 8-foot room were attracted to caged virgin females on a turntable in studies conducted at Riverside, Calif. The ratio of males attracted to lemon cages containing 25 virgin females versus lemons without females varied from 100:1 to 300:1. Virgin females were most attractive to males when 4 to 5 weeks old. Attractive virgin females exposed to mating one afternoon became totally unattractive to males by the next afternoon.

When reared at 80° F, about 88% of the adult males of a given generation of California red scales emerged within 3 days after emergence began. During August, daily emergence began between 3:30 and 5:00 PM at illumination levels of 700-1000 ft-c and practically ceased at 8:00 PM when the illumination level had dropped to approximately 1 ft-c. About 3% of the total daily emergence occurred between 8:00 PM and dawn.

At Weslaco, Tex., infrared aerial photography is being evaluated as a survey tool for estimating brown soft scale populations. An increase in scale

population was detected by this method, apparently through differences caused by an increase in sooty mold, which is correlated with scale build-up.

Problems in rearing the brown soft scale during the winter months in Texas were encountered when the citron melons used for laboratory rearing did not hold up well in storage. Mexican squash, Cucurbita moschata, the most promising of several substitutes tried, was an effective host one generation after the scale was allowed to adapt from the citron melons.

In laboratory studies of the fecundity of brown soft scale, crawlers were produced approximately 33 days after the scale had attached. The average number of crawlers produced per female per day ranged from 9.8 to 66.3 between the 41st and 55th day. Significant numbers were still being produced at this time.

In India (PL 480 project A7-ENT-26) 4 species of gall midges affecting the inflorescence of mangoes were identified. Dasineura amaramanjarae Grover, Procystiphora mangiferae (Felt), and P. indica n. sp. infest the blossoms. Erosomia indica n. sp. infests the floral buds, axis of the inflorescence, and the newly-formed fruit and is considered the most serious of the four. Bud damage caused by D. amaramanjarae was estimated at 25 to 30% and that of P. mangiferae was estimated at 60 to 70%.

A citrus blossom midge determined as Dasineura sp., discovered on sweet lime in India in 1964 (PL 480 project A7-ENT-35), was also found attacking many other varieties of citrus. From 50 to 77% of the flower buds were infested with a range of 2-43 larvae/bud. Infested buds become distorted and fall. This is the first Dasineura and the 3rd gall midge reported in association with citrus blossoms.

Surveys in India (PL 480 project A7-ENT-47) also indicated the presence of the midge, Udumbaria nainiensis Grover, on figs in northern India but apparently not in the southern portion. During October-November, the eggs are deposited in the cavity of the young fruit and the larvae consume the floral inflorescence, resulting in aborted non-edible fruits.

2. Subtropical Fruit Flies. Studies in Mexico City revealed that the eye color of Mexican fruit fly pupae during pupal development is a reliable indicator for age. At 80° F the eyes were white up to the 7th day, yellow from the 8th to 9th day, light brown to red brown from the 10th to the 12th day, and iridescent from the 13th to the 15th day. In order to avoid excess radiation damage to emerging adults, Mexican fruit fly pupae should be exposed to gamma radiation 3 days before emergence or when the eyes are in the red-brown color stage.

An attempt is being made in Mexico City to establish laboratory colonies of 3 species of Anastrepha other than A. ludens, the Mexican fruit fly. The purpose is to broaden the scope of olfactometer studies. Candidate materials not attractive to A. ludens may be attractive to other species. Rearing

techniques similar to A. ludens have been developed for A. serpentina. Egg production for A. mombinpraeoptans and A. striata has not been satisfactory and will need further research.

In Mexico City an impure lot of hydrochloric acid severely curtailed the laboratory production of adults of the Mexican fruit fly for 3 months. Larvae produced from medium prepared with this acid were apparently normal in size, vigor, color, and percent entering medium from eggs, but mortality occurred shortly after pupation, resulting in only 1 to 3% adult emergence. The exact mode of action of the impurity could not be determined.

In Hawaii progress was made on the improvement of fruit fly larval diets during the production of 180 million eggs and 109 million pupae. The flies were used largely to support sterile fly release programs and other research. A significant new development was the discovery that Gelgard (a fire-fighting polymer) could be used to control moisture and physical structure of a wheat middlings-shorts-sugar medium that not only replaces the high-cost carrot powder but permits greater production per unit of lateral space as well as depth of medium. The medium also includes torula yeast, a discovery of the Mexico City laboratory, HCL, Nipagen, sodium benzoate, and water. In tests involving several million eggs and multiple generations of fruit flies, dependable production of the Medfly and the oriental fruit fly was possible at a material cost of less than $16 per million, compared with $30 per million one year ago. Further research on modifications for melon fly production promise to make possible savings of at least $25 per million for this species.

Diets of sugar and/or protein hydrolysate exposed to 500 kr gamma radiation had no adverse effect on behavior, survival, fecundity, fertility or reproduction by 3 species of fruit flies. Larval development, as well as the F_1 generation adults, also showed no adverse effects.

Attempts in Hawaii to utilize the oriental fruit fly and melon fly throughout the normal working day for research on sex behavior led to the discovery that the time of mating was determined not only by a diminishing light intensity but also by either a predetermined rhythm or a minimum period of daylight exposure. Flies reared in a reversed diurnal rhythm mated readily under diminishing light in the morning hours after removal from their artificial environment.

In studies at Miami, Fla., basic techniques were developed for mass rearing the fruit fly, Anastrepha suspensa. The Mexican fruit fly larval medium proved to be acceptable, whereas the medium used in the Hawaii Fruit Fly Laboratory was too moist. Cheesecloth-paraffin oviposition shells were accepted by the flies for oviposition.

3. Guava Weevil. Life history studies with the guava weevil (Conotrechetus dimediatus) in Mexico City revealed that a diapause takes place in full grown larvae in the soil for 4 or 5 months. Pupation occurs about 1 month

before transformation to adult. The larval diapause enables the weevil to bridge the host free period which occurs between November and May.

B. Insecticidal and Cultural Control

1. Citrus Insects and Mites. At Riverside, Calif., Temik applied as a 10% granular formulation to the soil surface at the base of citrus trees provided long residual systemic activity. Application of 1.2 g active ingredient per ft^2 gave effective control of the citrus red mite for at least 61 weeks after treatment on potted orange trees. Similar applications to 2-year-old navel orange trees in the field provided effective mite control for 44 weeks and controlled citrus thrips and spirea aphid for 10 and 29 weeks, respectively.

Aerial applications of methyl parathion, malathion (technical and dilute), azinphosmethyl (concentrated and dilute), and carbaryl at dosages designed to suppress but not completely control brown soft scale were applied to a heavily infested citrus grove (240 acres) in Hargill, Tex., to determine the effects on the scale and parasite populations. Methyl parathion caused a pronounced increase in scale population, whereas the other materials had a suppressive effect. Parasites continued to appear in the groves as long as significant numbers of scale were present, despite the repeated use of the pesticides.

Brown soft scale on potted citrus trees in Texas showed a 78% decline 2 weeks after the application of 4 g of 10% Temik granules on the soil. Between 8 and 15 weeks after treatment, control was 100%, after which scales started to reappear in small numbers. Seventeen weeks after application, all treatments were significantly below pretreatment infestation levels while the check had increased by 86-fold. A plant receiving 3 g of Temik was free of scale from the 11th to 13th weeks, while a dosage of 2 g failed to eliminate the scale but suppressed it from the 4th to 13th weeks.

At Orlando, Fla., 51 chemicals were screened for effectiveness against citrus rust mite. Of these, 7 gave at least 95% kill when tested as low as 1 ppm, and 9 additional materials were effective at 2 ppm.

C. Insecticide Residue Determinations

1. Citrus Insects and Mites. Drift studies at Weslaco, Tex., involving aerial applications of methyl parathion continued to show heavy deposits up to 400 feet from the flight line and in one test heavy deposits were recorded at 800 feet. The latter occurred when the wind direction was directly at right angles to the flight line and the horizontal and vertical wind speeds were lower than in 3 other tests. Filter paper samples gave a clearer picture of the drift patterns than citrus leaves. Prespray levels of methyl parathion and DDT were high on the leaves, apparently the result of drift from cotton and other sprays or build-up from previous drift tests. In bioassay tests, almost complete kills of the parasite, Coccophagus lycimnia, were obtained 400 feet from the flight line and there were few survivors at

800 feet. The coccinellid, Hippodamia convergens, proved highly susceptible to methyl parathion drift, indicating that predator populations could be severely decimated by exposure to drift from this insecticide.

Aerial sprays involving malathion, low volume technical and dilute, demonstrated great variation in drift, depending on weather conditions and mechanical factors. Early tests had indicated that dilute formulations drifted to a much greater extent than the technical. Later observations showed a complete reversal in some cases and other instances where the materials drifted approximately the same distance. Since the equipment and dosages were approximately the same, indications are that temperature, humidity, wind direction, wind velocity, and turbulence have a profound influence on the distance the spray materials may drift.

2. Other Insects. In studies at Hoboken, N.J., methyl bromide remained at relatively high concentrations in the centers of large bags of some seeds for long periods during the aeration period following fumigation. Concentrations of up to 7.5 oz/1000 ft^3 (15.6% of the original 48-oz dosage) were found after 20 hours in a 110-pound bag of Pinus mugo seeds. Some other conifer seeds had concentrations of near 2 oz/1000 ft^3. Bags of most other seeds contained only a few ppm.

3. Analytical Equipment. At Hoboken, N.J., further tests on chemical gas detector tubes to determine whether hazardous gas concentrations are present in working areas confirmed the usefulness of the Kitagawa tubes for detection of methyl bromide and ethylene oxide at or below concentrations harmful to personnel. However, they were not satisfactory for detection of hydrogen cyanide at low concentrations. In preliminary tests, the Draeger tubes for detection of hydrogen cyanide appeared useful at concentrations that would be hazardous to personnel.

D. Biological Control.

1. Citrus Insects and Mites. When the parasites, Encyrtus lecaniorum and Metaphycus stanleyi, were introduced into caged citrus trees infested with brown soft scale at Weslaco, Tex., E. lecaniorum was maintained for at least 9 months, while populations of M. stanleyi diminished after 3 months. E. lecaniorum suppressed but never eliminated the scale populations during this period. The cage was removed from the tree in late spring in order to release the remaining E. lecaniorum in an effort to establish this parasite in the field. Earlier attempts at establishment by adult releases had proved unsuccessful.

Coccophagus lycimnia continued the most abundant parasite of the brown soft scale found in the Rio Grande Valley, constituting in excess of 90% of the parasites collected. Microterys flavus was the second most abundant parasite species. Parasite population trends were similar to the previous year, although lower in number. No parasites were found in the 20 survey groves from June to August, a period of high insecticide usage, and the highest number of parasitized scale was recorded in December.

The interrelationship between pH and salt concentration of virus suspensions appeared to influence deactivation of the noninclusion virus of the citrus red mite in studies conducted at Riverside, Calif. When mite colonies on lemons were sprayed with virus suspension prepared with a buffer of unknown salt composition and molarity at pH values ranging from 3.0 to 12.0, infections were obtained within pH values of 5.0 to 7.0. Additional tests using phosphate buffers at 0.067 M and 0.033 M concentrations demonstrated that the virus was infective between a pH range of 5.35 to 7.38 with the higher concentration of salt and between pH values of 5.0 to 8.1 with the lower salt concentration.

In cooperation with the Department of Biological Control, University of California, 3 species of predatory mites--Amblyseius hibisci Chant, A. limonicus Garman and McGregor, and Typhlodromus occidentalis Nesbitt--when fed a sole diet of citrus red mites infected with a noninclusion virus, lived as long and deposited as many eggs as those fed normal citrus red mites, indicating no detrimental effects of the virus on the predatory mites.

In cooperation with Rincon Insectary, leaf samples collected from 51 citrus groves in central and southern California and sent to Riverside, Calif., for correlation of mite infestation level with incidence of the citrus red mite virus showed that infected mites were present in 27 of the groves, in 8 counties, and on all varieties of citrus represented. High incidence of disease was associated primarily with high population density but was also present in low populations. Epizootics had occurred previously in most of the low population groves.

A natural epizootic of the citrus red mite virus found during January 1965 in a 12.5-acre grove near Riverside, Calif., was surveyed at weekly intervals for 1 year and bi-weekly intervals for an additional 6 months to correlate mite population trends with presence of the disease. An infestation averaging approximately 40 mites per leaf was reduced by the epizootic during a 4-month period, after which the populations fluctuated between 1 to 8 motile forms per leaf, except for 2 minor peaks averaging 10 mites per leaf. A scalicide applied in the fall of 1965 to all except the 15 trees being sampled may have depressed the virus disease by isolating the 15 trees from free migration of mites between trees. Diseased mites were collected in all but 4 of the 63 surveys. Those negative for the disease occurred within the 3-month period following application of the scalicide.

The number of leaves on a mature Hamlin orange tree were counted at Orlando, Fla., in studies to establish models as a means of estimating total populations of insects and mites on citrus. The tree, 18'11" high, with a skirt width of 17'6" and with moderately dense foliage, contained 140,527 leaves. Of these, 111,658 were of the current year's spring flush of growth and 28,869 were of earlier growth flushes. The average area per leaf of the spring flush leaves was 5.8 in^2; that of the older flush leaves was 9.3 in^2.

2. Subtropical Fruit Flies. A bacterial pathogen of the Mexican fruit fly discovered during the course of chemosterilant screening was determined to be Serratia marcescens Bizio. This is the first time that this microorganism has been recorded as being a pathogen of A. ludens.

An entomogenous fungus in the order Laboulbeniales was found in fairly large numbers on adult Mexican fruit flies in a mango grove in Santa Catarina, Morelos, Mexico, during February and March 1966. Four percent of around 4,500 flies examined were attacked and of these nearly 99% were males. The fungus was found on all parts of the insect including head, antennae, thorax, abdomen, legs, and wings.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Citrus Insects and Mites. Extracts of California red scale female sex pheromone prepared by various procedures at Riverside, Calif., differed in their relative attractiveness to males. A diethel ether extract of the condensate of cold-finger-trapped air passed over virgin females appeared the most attractive of 7 different preparations. An ascending thin layer chromatogram of this extract developed with n-hexane-diethel ether-ethanol produced a major spot with an R_f of 0.9 and ellicited male copulatory response. Fifty µl of this extract placed on dummy females of paraffin drops confined in Munger cells on lemons and compared with 1, 10, and 100 similarly confined virgin females exposed to males in free flight attracted approximately the same numbers of males as the 10 live females, indicating that 1 µl of the extract had 0.2 female equivalents of attractiveness.

Males of the California red scale were sterilized by permitting young adults to contact tepa residue on glass surface for 15 to 30 minutes. Twenty to 40% of the females mated to males contacting 0.25 to 0.75% residue produced crawlers, whereas reproduction of untreated females was 98 to 100%. There was evidence that when females were mated with males contacting substerilizing dosages of tepa, there was an increase in male to female ratios in the F_1 and F_2 generations.

In studies at Weslaco, Tex., irradiation of third stage brown soft scale on Mexican squash was explored as a means of releasing pre-emergent parasites in citrus groves without adding to the biotic potential of the natural scale population. When exposed to 5,000 and 10,000 roentgens of gamma radiation, the scales produced limited numbers of crawlers beginning on the 43rd and 44th days, respectively. At dosages of 20,000 and 40,000 r, no crawlers were produced. Untreated scales began normal reproduction on the 42nd day. The crawlers produced at the 2 lower dosages were weak and showed a more pronounced pink coloration than that found in crawlers from unirradiated scale.

2. Subtropical Fruit Flies. In studies at Miami, Fla., to establish an effective radiation dosage for sterilization of Anastrepha suspensa, the reproductive systems of males showed severe damage with no recovery at

dosages of 2,000 r of gamma radiation. No eggs were laid by females that had received 3,000 r or above. The maximum dosage tried, 18,000 r, caused severe damage and heavy mortality to the flies.

With mass rearing methods now available, this information on sterilization dosages establishes a basis for use of sterile male releases for control or eradication of this fruit fly. In lure tests conducted with field populations of A. suspensa, candidate lures were applied to the surface of sticky board traps. Lures that were promising were ENT numbers 26,660X, 26,663X, 28,461, 44,462X, 44,620, 44,624, and 50,022a. Cottonseed hydrolysate and casein hydrolysate were used as standards.

In Mexico tests were conducted to determine if intensive trapping with glass traps baited with cottonseed-hydrolysate-borax would reduce Mexican fruit fly populations and prevent infestations in orange and mango crops. One test in 87 mango trees with 1 trap per tree reduced the population by 60.2% and decreased the larvae per pound of fruit from 23.4 to 3.3. With 3 traps per tree in a semi-isolated mango grove of 212 trees, Mexican fruit fly infestations were reduced from 40 to less than 1 larva per pound. Intensive trapping in a navel orange grove of 2,000 trees with 1,000 traps in Xalapa, Veracruz, Mexico, reduced the on-tree fruit infestation about 50%, as compared to infestation in adjoining section of the grove separated by 8 rows of trees.

In Hawaii a new 30,000 curie irradiator that permits a dose rate of about 5 kr/min has caused irreversible sterility in Medflies irradiated with 5 kr, whereas 9 kr was required in the old USDA-416 curie equipment. The old treatment involved 5 minutes holding of the pupae in cannisters and 10-15 minutes exposure period which may have induced anoxia. Sixteen thousand flies exposed as 7- to 8-day-old pupae for 1 minute to 5 kr immediately after packaging deposited only 4 eggs, all of which were non-viable. A similar lot held for 15 minutes after packaging before irradiation produced 2,700 eggs, of which 3.4% hatched. Metabolic heat raised the temperature in the package from 78 to 82° F. A 9 kr dosage is still required for the melon fly and oriental fruit fly in the 30,000 curie unit to prevent egg deposition and insure irreversible sterility. The larger size of these species (30,000-35,000 pupae per liter vs. 55,000 for Medfly) apparently insured retention of enough air among the pupae to avoid any anoxia during the 15-20 minutes they have been held in the cannister.

The Hawaii station supplied the Guam Department of Agriculture with 8 million sterile oriental fruit flies between July 2 and August 7, 1965. These were released to suppress a well-defined outbreak of this fruit fly. Eradication was again accomplished and no wild flies have been taken on Guam in the last 11 months (33,000 trap days prior to July 1). The male annihilation program (air distribution of methyl eugenol + naled on canec squares) had previously eradicated the species from Saipan, Tinian, Aguijan, and Rota.

In Hawaii a Stickem-coated trimedlure-baited Medfly trap was 50 to 100% more effective than the standard Steiner trap when traps were 50 to 100 feet apart but was 35 to 65% less effective when each trap was given 2 or more acres to draw from. Medflies, attracted by trimedlure and other male Medfly lures, accumulate in the vicinity of the trap and enter slowly. This behavior is believed to give sticky traps an advantage by earlier interception of flies as they move about prior to their final approach. Stickyboards may therefore catch some of the flies brought to their vicinity by competing traps.

In Hawaii maximum concentrate protein hydrolysate-technical malathion bait spray has given promising results for the suppression of 3 species of adult tropical fruit flies. The new formula uses no water other than the 50% moisture in the PIB-7 protein hydrolysate and at the usual 1:4 technical malathion-PIB-7 ratio can be quickly pumped to a molasses-like consistency that will not separate with low agitation nor lose significant amounts of moisture from falling droplets. The conventional bait sprays, because of moisture loss, must be applied from low altitude and under moderate temperatures to avoid droplet shrinkage and excessive drift. The maximum concentrate formula was applied from elevations of up to 400 feet in the 100-foot swaths as much as 200 feet apart, which reduced flying 80%, increased the safety over rugged terrain, permitted work in windy weather, and reduced spray load per square mile by 70%. The technical malathion bait spray was as effective as full coverage low-volume technical malathion sprays without the protein hydrolysate at one half the rate of toxicant per square mile.

The new malathion-PIB-7 formulation was used by pest control agencies to eradicate a new incipient Medfly infestation discovered in Brownsville, Tex., in 1966, with preliminary indications of complete success.

Studies in Hawaii showed that formulations of cue-lure, methyl eugenol, and trimedlure with toxicant could be dropped separately or as a combined mix for simultaneous eradication of the 3 species of tropical fruit flies by the male annihilation method. In standard tray tests there were no significant differences in the kill of oriental, melon, or Mediterranean fruit flies when the 3 lures were applied as a single foliage application with naled as the toxicant and Myverol as the thickener as compared to interspersed discrete droplets of each of the 3 separate lure formulations.

In Hawaii tests continued with a new thickener for foliar applications of grease-like deposits of male lures with toxicants. In tests with trimedlure, medlure, methyl eugenol, and cue-lure, CAB-O-SIL (a pyrogenic silica of very small particle size) at 7 to 12% produced thixotropic mixtures of consistencies comparable to those obtained with Myverol. CAB-O-SIL can be mixed quickly when cold. Compared with Myverol, this thickener leaves a drier deposit that tends to flake off. Both CAB-O-SIL and Myverol deposits of cue-lure-naled on thick foliage remained effective for periods of more than 2 months.

Aerial applications of cue-lure-naled formulations with the extender (Myverol) were tested in Hawaii against melon fly populations. Each test involved about 5 mi^2 with applications at 4 to 6 week intervals of cue-lure plus 5% naled, plus 8 to 12.5% Myverol at rates of 5 to 6 lb/mi^2. The liquid formulation was discharged from the aircraft in discrete ejections of a few milliliters at a time by means of a hand operated grease pump. Various combinations of dosage, percent Myverol, swath width, and altitude were tried. The male catches of 99% below the immediate pretreatment value was obtained with 6.4 lb/mi^2 of a formulation containing 12% Myverol applied in flight lines 600 feet apart from 500 feet above the ground. Wider spacing of the flight lines or distance between ejections, lower dosage, or more fluid formulas with less Myverol gave less satisfactory results. A similar test of 2 applications of 83% cue-lure, 5% naled, and 12% (by wgt) CAB-O-SIL (EH-5) at the rate of 6.7 lb/mi^2 was conducted in the same area several months later. Applications were made at 4 week intervals in swaths 500 feet apart from 700 feet elevation. Pretreatment catches of male flies in cue-lure traps within the area averaged 120 per trap day. Male catches were reduced 99.3% within 24 hours, 99.9% in 5 days, and were still 99.0% less at the second application, which reduced the catch another 95%. The treated area contained a 14x larger population at the time of the first treatment than the control areas on similar slopes north and south of the plot. The population in the controls 39 days later was unchanged. Evidence was obtained that these applications caused a rapid and substantial male melon fly population reduction up to $\frac{1}{2}$ mile downwind. Immigrating fertile females prevented any infestation reduction in host fruit. The female/male ratio of 1.1 to 1 in liquid bait catches before the first application changed to 20:1 within 3 weeks. In the control areas female/male ratios remained unchanged. Of 262 females caught in liquid baits when the ratio was 20:1, 58% were gravid and 69% of these had mated. Of non-gravid females, 12% had mated. Of all females, 55% had not mated. This method and formula appears sufficiently developed for large-scale use against isolated populations. The cost for materials and application would be about $75 per square mile per application.

In Hawaii large-area tests of 2 applications of 85% medlure, 5% naled, and 10% Myverol (percent by wt) were applied on an area of moderate Mediterranean fruit fly population. The first application on 4.8 mi^2 at the rate of 5.3 pounds of mixture per square mile in flight lines 1,000 feet apart reduced the male population by only 64%. The second application at the rate of 9.28 pounds of mixture per square mile from flight lines 500 feet apart produced a maximum reduction of 73%. Plans for additional Medfly tests on isolated populations of the Medfly in the Azore Islands are being developed.

In Hawaii fruit fly bait sprays of protein hydrolysate-technical or wettable powder malathion caused permanent damage to auto finishes of all types used on new or recent models when droplets were applied to panels heated by full sunlight and allowed to remain several hours. However, droplets from aerial sprays under cool conditions marked acrylic and nitrocellulose lacquers and acrylic enamel but not alkyd enamel after 20 hours' exposure. Droplets washed off with a mild cleaner after $\frac{1}{2}$ hour caused only light stains on the

most susceptible finishes. Acrylic enamel and lacquer were permanently marked after exposures of only one hour. Droplets of a mixture of 2 pounds Zectran 25% wettable powder plus 1 quart PIB-7 per gallon of spray left only light, easily removable stains on all finishes, including acrylic lacquers and enamels after 4 hours' exposure in sunlight. The Zectran formulation is the least injurious to auto finishes of any effective substitute found to date for malathion in protein hydrolysate bait sprays.

3. Southern Green Stink Bug. In Hawaii, when 5th instar nymphs of the southern green stink bug were subjected to gamma radiation dosages of 2, 3, 4, 5, 8, or 12 kr, only the females treated with the two lower dosages deposited eggs but none hatched. A proportionate increase in nymphal and adult mortality resulted with increase in dosage. In another test females irradiated with 3 kr were paired with normal males. Of 26 pairs used initially, a total of 833 eggs were obtained with 0.9% hatching. Normal females paired with irradiated males at the same dosage deposited 1,631 eggs of which 4.9% hatched from 13 pairs. Twenty-six pairs in the control produced 3,207 eggs, of which 46.6% hatched.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. Subtropical Fruit Flies. In Hawaii the use of modified atmospheres of low oxygen levels to protect fresh fruits during treatment with gamma radiation requires an increase of the minimum disinfestation dose. Fricke dosimeters saturated with atmospheres containing 0.01 to 1.0% oxygen showed that the expected dose was halved. The expected dose was halved by 100% carbon dioxide or 99.9% nitrogen.

In Hawaii the minimum disinfestation dose for fumigation of papayas wrapped in tissue and packaged in ventilated orange cartons at 50° or 60° F with ethylene dibromide was 24 oz/1000 ft^3 for 2 hours when the fruits were refrigerated at 42±2° F for 1 to 3 days after 3 hours of aeration at 60° F. The total insect population tested was more than 126,000. No survivors were obtained when the fumigated fruits were aerated at 60° F for 24 hours and then refrigerated. No survivors were obtained when the fumigated fruits were refrigerated at 49±1° F after the 3- or 24-hour aeration periods.

The appearance, flavor, and aroma of Euphoria longan (Lour.) Steud was not significantly altered by fumigation with ethylene dibromide at the dose of 8 oz/1000 ft^3 for 2 hours at 70° F when the treatment was followed by storage at room temperatures of 66-88° F or at 45° F.

Cold storage at 45° F before and after treatment at 45° F did not affect the mortality of the Mediterranean, melon, and oriental fruit flies in papayas packaged and irradiated in modified papaya cartons at the dose of 21 kr. Refrigeration reduced the pupation of moribund larvae with time.

Chinese peas required continuous refrigeration at 35° F to tolerate irradiation up to 50 kr.

2. Mango Weevil. In Hawaii the minimum disinfestation dose for adult mango weevils was 25 kr of gamma radiation. At this dosage all larval stages were killed and pupae and adults were effectively sterilized.

Standard vapor heat treatments were ineffective against adult mango weevils in the seeds of mangoes. One-hour ethylene dibromide dip treatments at 120° F appeared to be effective but resulted in a serious residue problem.

3. Other Insects. At Hoboken, N.J., the methyl bromide-resistant Cecidomyid, Plemeliella abietina, and a seed chalcid, Megastigmus sp., found infesting spruce seeds imported from Europe were effectively controlled in small-scale, 24-hr atmospheric fumigations at near 72° F by carbon tetrachloride-carbon disulphide 80-20 mixture (by volume) at a rate equivalent to 4 and 6 lb/1000 ft^3 of the carbon disulphide (20 and 30 lb of the carbon tetrachloride). Preliminary tests indicated good tolerance to this fumigant at these schedules by Pinus nigra seeds.

In further tests of various wrappings or packaging materials in New Jersey, aluminum foil and Styrofoam, occasionally used with imported plants or commodities, were highly impervious to methyl bromide. Only 3.3% and 27.1%, respectively, of the chamber concentration permeated through the samples in 8 hours. These materials require removal, opening or perforations prior to fumigation to insure effective treatment. A manila envelope used for seeds with a permeability of 67.1% in 1 hour was recommended for corrective action for use during 2.5-hr fumigations pending further study.

In preliminary tests in New Jersey at temperatures near 91-93° F, atmospheric fumigation with 3 lb/1000 ft^3 of methyl bromide for 2.5 hr was found to be the minimum effective schedule for Bruchus rufimanus adults in faba beans from the Mediterranean area. Occasional survival of these or other bruchids in various host seeds has occurred with 3 lb for 2 hr or 2.5 lb for 2.5 hr at these temperatures.

In small-scale tests there was little or no difference in resistance to fumigation with methyl bromide or ethylene oxide-carbon dioxide 10-90 mixture between lots of the snail, Theba pisana, received from Italy in April, May, or August 1965. There was an apparent increase in resistance as the temperature of the fumigation was lowered from near 50° to near 40° F and the effect was more pronounced at lower temperatures.

I. Insect Vectors of Diseases

1. Citrus Insects and Mites. In vector studies at Orlando, Fla., to determine the possibility of multiple transmission of tristeza virus by melon aphids transferred to a succession of indicator plants, 3 transmissions appeared among plants of the second series, indicating need for more study. In tests of 200, 400, or 800 melon aphids per indicator plant, the number of transmissions increased with the aphid population per plant, but additional trials will be required before definite conclusions are drawn. There was

also evidence that the rate of aphid transmission of tristeza virus decreased as new growth matured, from the third week and thereafter. In preliminary tests of whiteflies as possible vectors of tristeza virus, 1 indicator plant in 20 trials showed vein-clearing symptoms typical of this virus, the first suggested implication of whiteflies as vectors of this disease.

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AREA NO. 5. FORAGE AND RANGE INSECTS

Problem. Numerous insect pests that attack forage and range plants in various parts of the United States lower seed production, reduce the quantity and quality of forage crops, and decrease the abundance of range plants for the grazing of livestock. Certain insects are involved in the transmission of forage-crop diseases. Among the more important insect pests are grasshoppers, lygus and other plant bugs, stink bugs, seed chalcids, the alfalfa weevil, root borers, spittlebugs, leafhoppers, and a variety of aphids including the spotted alfalfa aphid and the pea aphid. A variety of insecticides is used to control these insects but they are often costly and may create residue hazards in meat and milk as well as adversely affect wildlife. There is great need for more efficient insecticides that can be applied on forage crops and range vegetation without leaving residues harmful to man or animals or that might harm bees and other pollinating insects. Increased attention should be given to the development of non-chemical control methods. The search for insect parasites, predators, and pathogens and ways to employ them effectively should be emphasized in research. The development of crop varieties which resist attack by insects offers economical and safe insect-control procedures. Forage crops should be evaluated for resistance to major insect pests and resistant germ plasm should be made available for use by the plant breeders in crop-improvement programs. Basic studies are also needed on the feeding habits of grasshoppers under different environments that affect the abundance of these insect pests. New approaches to control of forage and range insects, such as sterilization techniques and sex attractants, should be investigated.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-term program of basic and applied research on forage and range insects. Studies on varieties of alfalfa resistant to insects are cooperative with State and Federal agronomists and plant breeders, those on plant disease transmission by insects with plant pathologists, and research on insecticide residues with chemists. Grasshopper research at Bozeman, Mont., and Mesa, Ariz., is cooperative with the respective State Experiment Stations. White-fringed beetle research is conducted at Gulfport, Miss. Biological control studies on armyworms and cutworms at Baton Rouge are cooperative with the Louisiana Experiment Station. Investigations on alfalfa insects are being conducted at Mesa, and Tucson, Ariz., Lincoln, Nebr., and Beltsville, Md., in cooperation with the Experiment Stations in these States. Research on clover and turf grass insects at Forest Grove, Oreg., is conducted in cooperation with the Oregon Experiment Station. Work on grass insects, plant disease transmission by insects, and insecticide residues at Tifton, Ga., is cooperative with the Georgia Experiment Station. Research on insecticide residues is conducted at Beltsville, Md., and at Yakima, Wash.,

in cooperation with the Washington Experiment Station. Studies on varietal resistance, insect vectors of plant diseases, and grass insects at University Park, Pa., is cooperative with Experiment Stations in 12 Northeastern States. Certain phases of the research on forage and range insects are contributing to regional projects W-37 (Natural Factors Responsible for Grasshopper Population Changes), NC-52 (Factors Influencing the Distribution and Abundance of Grasshoppers), W-74 (Seed Chalcids Attacking Small-Seeded Leguminous Crops), and S-55 (Alfalfa Insects).

Two contracts, 10 grants, and 1 cooperative agreement with State Universities and Experiment Stations will provide additional research on insect biology, physiology, and nutrition, biological control, attractants, and varietal resistance.

The Federal scientific effort devoted to research in this area totals 24.0 scientist man-years. Of this number 4.5 man-years are devoted to basic biology, physiology, and nutrition, 5.0 to insecticidal and cultural control, 4.0 to insecticide residue determinations, 4.0 to biological control, 0.6 to insect sterility, attractants, and other new approaches to control, 0.5 to evaluation of equipment for insect detection and control, 4.1 to varietal evaluation for insect resistance, 0.2 to insect vectors of diseases, and 1.1 to program leadership.

In addition Federal support of research in this area under contracts and grants provides a total of 3.2 scientist man-years. Of this total 0.9 is devoted to basic biology, physiology, and nutrition, 0.6 to biological control, 0.3 to insect attractants and other new methods of control, and 1.4 to varietal evaluation of insect resistance.

Two P.L. 480 projects are underway: E21-ENT-9, "Insect Vectors of Virus Diseases of Various Forage Legumes" with the Research Institute of Plant Protection, Poznan, Poland, and A10-ENT-6, "Acoustic Responses of the Desert Locust (Schistocerca gregaria Forsk.), Moroccan Locust (Diciostarus maroccanus Thbg.), and Acrotylus insubricus Scop. (Orthoptera, Acrididae)" with the Hebrew University of Jerusalem, Jerusalem, Israel.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 44.5 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Grasshoppers. Severe drought and poor vegetation conditions in the spring of 1964 and the summer of 1965, reduced the desert grasshopper population in Arizona, but above-normal rainfall and better condition of desert vegetation in late 1965 and the early part of 1966 was favorable for an increase in this grasshopper species in 1966.

The average grasshopper population in rangeland habitats at Peeples Valley, Ariz., increased 73% in 1965 over that in 1964. This was the second successive increase. Winter and spring rainfall was considerably above normal and vegetative ground cover increased from 69% in 1964 to 77% in 1965.

In 1965 in Arizona, the grasshopper population increase in Conservation Reserve land was 368% over 1964, and in weedy field margins the increase was 330%.

To determine the affect of crowding on the migratory grasshopper, groups were reared in cages at the rate of one to 3.5 cu. in. and at one to 0.6 cu. in. There was no significant difference in the average length of the nymphal period, percentage survival, and body measurements and front wing deformity of resulting adults, at the 2 nymphal densities.

The percentage of migratory grasshopper eggs that hatched was greater for females that were exposed to males of the same age throughout the adult period than for females that were exposed to males for only the first 29 days of adult life, and still greater than for females that were exposed to males for only the first 17 days of life. The shortest adult longevity was in the group of females exposed to males throughout the adult period. Hatching percentages were low for eggs laid during the latter part of the oviposition period regardless of the length of the period the adult females were exposed to males.

Range grasshopper studies were continued in 1966 on several shortgrass rangelands in central and southeastern Arizona to determine the effects of weather, type, and condition of vegetation, range usage and management practices, and natural enemies on seasonal history, abundance, and plant damage of important grasshoppers. Populations of spring-group and summer-group grasshoppers were low owing to dry plant conditions in June and early July 1965 that were unfavorable for grasshopper development and survival.

Studies were continued on two 20-acre range recovery plots. Each plot is subdivided into 2 fenced and 2 unfenced 5-acre plots. On a sparse grass area for the period April-July 1965 average square-yard grasshopper densities in untreated fenced and grazed plots were 1.51 and 1.44, respectively. Loss of weedy and grass herbage in spring was negligible due to an abundance of vegetation; whereas on a comparable date in 1964 the loss of weedy forage was about 95%.

Research was initiated in Israel under PL 480 project to study the acoustic response of grasshoppers. Sounds emitted by male grasshoppers are made of compound pulses; the number of these in 0.5 seconds is called pulse rate. There was a marked increase in the pulse rate within the temperature range of 20° to 35° C whereas there was no marked increase at the 40° and 45° C. The age at which males started to emit stridulatory sounds was directly related to the temperature at which they

were reared. At 25° C they emitted sounds 24 days after reaching the adult stage, at 30° C 16 days, and at 44° C 5 days.

A grant was recently awarded Kansas State University to determine the food habits of selected grasshopper species when allowed a choice between range-inhabiting plants and cultivated pasture plants.

2. Alfalfa Insects. In preliminary studies at Lincoln, Nebr., to determine if sexual forms of the spotted alfalfa aphid could be produced in environmental chambers, the test insects were subjected to day and night temperatures of 70 and 60° F., respectively, and 8-1/2 hours of light. After 8 generations under these conditions no egg laying forms appeared. Prior field observations have indicated that there are 2 strains of the spotted alfalfa aphid; one with the ability to produce sexuales when subjected to the proper conditions and the other without this ability.

At Tucson, Ariz., efforts were made to determine conditions under which a year-around supply of larvae of the Egyptian alfalfa weevil could be achieved for use in plant resistance studies. It seemed probable that the small percentage of non-diapausing F_1 adults obtained by rearing weevils under a short photoperiod was partially the result of rearing them at high temperature (90° to 70° F). The culture was lost when only 4 F_2 adults were reared and all diapaused. These studies indicate that diapause is obligatory in most individuals or that factors other than temperature and photoperiod are involved.

At Beltsville, Md., the non-diapausing laboratory colony of the alfalfa weevil started in 1961 has completed its 23rd generation with no apparent loss of vigor. The larvae are reared under 8 hours of light and 16 hours of darkness to prevent diapause.

The suitability of 7 legumes as hosts for the alfalfa weevil was determined in the laboratory. All have been reported as being naturally infested under field conditions. The criteria used were adult feeding, survival from egg to adult, and oviposition, all in isolation. Significant host differences were found for all 3 criteria with alfalfa and sweetclover being most suitable and equally so. All 3 factors were found to be significantly and positively correlated. Alsike clover, ladino clover, red clover, and hairy vetch were relatively unsuitable as hosts. The presence of a dietary oviposition stimulus in alfalfa and sweetclover was definitely demonstrated.

The attractiveness of steam-distilled volatile components of these legumes plus hop clover was determined in a series of concentrations. Only 3 (alfalfa, alsike clover, and red clover) produced significant attractancy. Sweetclover and hairy vetch were unattractive. Ladino clover and hop clover were repellent.

Periodic surveys in 10 alfalfa fields for adult weevils showed a 70% decline from the winter of 1964-65 to the winter of 1965-66. Average populations per square foot were 9.4 and 3.9 for November and March of 1964-65, and 2.9 and 1.1 for the same months of 1965-66. Larval populations tended to decline also with peaks in individual fields, 1000 per square foot in the spring of 1965, but only 580 in the spring of 1966. This is the first indication of a population decline in the East since the weevil was discovered in Maryland in 1952. Adult weevils apparently return to alfalfa fields in the fall at random. There is no correlation between numbers of adults per square foot and age of alfalfa stand, amount of fall growth, stand density, or surrounding habitat.

A grant was recently awarded to New Mexico State University to develop an artificial rearing method for sucking insects and to determine their nutritive requirements. Work to date has been to develop techniques for feeding aphids and lygus bugs through an artificial membrane.

A grant was recently awarded to the University of California to determine the toxic ingredient in the salivary glands of lygus bugs that cause injury when these insects feed on alfalfa.

3. Clover Insects. Experiments were conducted at Lincoln, Nebr., to determine if sexuales of the sweetclover aphid could be produced in the laboratory. Sexual forms containing eggs were produced after 2 to 3 generations at photoperiods of 8-1/2 hours and day-night temperatures of 70 and 60° F.

4. Grass Insects. A bromegrass seed midge, which has been under study at Lincoln, Nebr., since 1965 has now been identified as Stenodiplosis bromicola. This species, which is recorded as a serious pest of bromegrass seed in Russia, had not previously been known to occur in the United States. This species appears to be widespread within Nebraska--adult midges were collected in 4 east and central counties and damaged seed heads were collected in 11 counties from east to west across the southern part of the State. The insect appeared to enter diapause as the bromegrass seed reached maturity during the 1965 season. Adults were again present and active in eastern Nebraska bromegrass fields in 1966.

Studies showed that adult two lined-spittlebugs less than 1 day old caused less damage to Coastal Bermudagrass than those 1 to 5 days old. There was no difference in the amount of damage caused by unmated females and males 1 to 25 days old. However, 7 day old mated females caused more damage than 7 day old unmated females. A large proportion of female two-lined spittlebugs collected from light traps contained no eggs in their ovaries, suggesting that older females with mature ovaries probably do not fly to traps.

At Tifton, Ga., the fall armyworm was reared on millet grown in soil with varying fertility levels. In general, larvae fed millet from high nitrogen levels were heavier at 6 and 9 days of age than those fed millet

from other fertilizer levels. Pupal weights did not follow the same order as larval weights and the differences were less significant. The larval period to pupation was about 3 days longer for larvae fed millet grown on unfertilized soil than those fed millet grown on high fertilization levels.

At Tifton, Ga., pearl millet breeding experiments indicate that pollination is accomplished not only by wind, but probably also by insects. The major insect visitors in the vicinity of Tifton in 1965, were the honey bee, a bumble bee, Bombus impatiens, and a cantharid beetle, Chauliognathus marginatus.

At Forest Grove, Oreg., 11 species of sod webworms were found infesting lawn and turf areas. However, all of the major damage to commercial grass plantings in Oregon has been caused by one species, Crambus topiarius. This species is present from late May to early August and reaches peak abundance in mid-June. Several other species were present in low numbers in commercial plantings. Of the species infesting lawn areas, C. bonifatellus was most abundant and was present throughout the season. Damage by this species was difficult to find in lawns possibly because regular irrigation and fertilization of well kept lawns enabled the grass to outgrow the damage. A few species were found infesting range areas but in non-economic numbers.

5. White-fringed Beetles. At Gulfport, Miss., a laboratory technique has been developed for testing feeding preferences of white-fringed beetles when the adults are offered a choice of several species of plants.

All legumes tested were fed upon heavily. Other preferred hosts were rose, althea, gardenia, ivy-leafed morning glory, pecan, dahlia, cotton, and teaweed. Such plants as bamboo, bitterweed, broomsedge, dog fennel, fern, sow thistle, bull thistle, and yucca were not fed upon.

An artificial diet which appears to be equal to natural diets for white-fringed beetle adults has been devised in Alabama under a research grant with Auburn University. All artificial diets developed for white-fringed beetle larvae have been unsuccessful primarily because mold inhibitors required to prevent mold growth on the diet were lethal to the larvae.

B. Insecticidal and Cultural Control

1. Grasshoppers. Tests of low-volume applications of 6 insecticide formulations were made by airplane for grasshopper control of rangeland in Montana. Total volume per acre ranged from 7 to 21.3 ounces. Technical malathion at 6 ounces per acre was used as a check. Although all insecticides gave satisfactory control under some conditions, meteorological factors and physical characteristics of the spray materials were found to be of much greater significance in the low-volume method of treatment than with previously used larger volumes. For example the very fine

atomization of diazinon reduced its control, whereas fine atomization of naled appeared desirable.

At Bozeman, Mont., 5 insecticide formulations applied by low-volume ground equipment were compared with malathion for grasshopper control. Two were approximately equal to the malathion standard and 3 gave better control.

Laboratory screening tests at Bozeman, Mont., were conducted to determine the effectiveness of 34 candidate insecticides against adults of the migratory grasshopper. By use of a dosage-mortality regression line for analytical grade malathion, the approximate 80-90% dosage levels were determined for males (3.90 ug/insect) and females (5.80 ug/insect). These dosages were used for the candidate insecticides and the malathion standard. Acetone solutions of the insecticides were applied topically, or to lettuce discs in cases where oral tests were conducted, by means of a calibrated micro-syringe. Following treatment the grasshoppers were confined in screen cages with lettuce as food. Mortalities were recorded after 24, 48, and 72 hours. Three candidate insecticides were better than malathion and 2 were equally as effective.

2. Alfalfa Insects. Small plot tests were conducted at Beltsville, Md., comparing 28 experimental insecticide treatments with a methoxychlor-malathion standard to control the alfalfa weevil. All were applied to the growing crop in May 1966. Eight materials showed 5% or less foliage damage 20 days after application and seven other materials showing less than 10%. The addition of parathion to Shell SD-7438 and Sevin did not increase control, nor did the addition of malathion to methoxychlor.

Seven materials were compared for alfalfa weevil control on large plots. All were equally effective 7 days after application. Larval counts 20 days after application showed only azinphosmethyl (3/4 lb), Imidan® (1 lb), and methoxychlor (1-1/2 lb) significantly better than the untreated check. Other materials applied were carbaryl, malathion, parathion, and diazinon in order of their effectiveness.

At Lincoln, Nebr., 7 insecticides were initially equally effective in reducing nymphs of the tarnished plant bug, but DDT was effective over a longer period. None of the treatments provided control for the alfalfa seed chalcid. DDT increased the yield of seed by 163% over that of the check. None of the other treatments significantly increased yields.

In tests in Arizona to control the red harvester ant in alfalfa fields, Kepone bait gave 80% control of ant colonies 3 months after application compared with only 45% control with mirex bait.

3. Clover Insects. Since dieldrin has been withdrawn for use on sweetclover, tests have been initiated at Lincoln, Nebr., to find other insecticides for control of the sweetclover weevil. Bay 39007 is the only one

of 5 insecticides tested that has shown promise. Additional tests will be necessary to determine if it will protect the seedings long enough to be of practical value.

4. Grass Insects. At Tifton, Ga., Coastal bermudagrass plots that were mowed regularly for hay had little to no spittlebug damage while plots that were not mowed regularly had high numbers of spittlebugs and were badly damaged.

At Tifton, Ga., one of two granular insecticides applied at the rate of 1 pound per acre in each of 2 applications to 2 separate fields of Coastal bermudagrass in August 1965 to control an insect complex increased the yield 1/3 ton dry weight more per acre as compared to the check.

At Tifton, Ga., 4 of 6 insecticides applied to Coastal bermudagrass at 1 pound per acre gave good control of Mocis spp.

At Tifton, Ga., 7 insecticides applied at 2 pounds per acre were evaluated for control of mole crickets in millet. Effectiveness was based on dead crickets, tunneling, stand reduction, and yield. The 4 best insecticides, based upon the various indices of effectiveness were trichlorfon granules, Mobil MC-A-600 granules, Stauffer N-2790 bait, and Kepone bait.

5. White-fringed beetles. In an effort to develop an insecticide screening method for white-fringed beetles, newly hatched larvae were placed in direct contact with heptachlor, dieldrin, or DDT and older larvae were dipped in acetone solutions of several insecticides. The younger larval were not killed and results with the older larvae were inconsistent.

Balled and burlapped nursery plants (ornamentals) infested with white-fringed beetle larvae were dipped in solutions of ethylene dibromide formula No. 440 and ethylene dibromide chlordane formula No. 431 for about 15 minutes. Two weeks later all larvae were dead in plant balls treated at the 4 ml/gal dosage of each. A few larvae were classified as moribund in plant balls treated at the 2 ml/gal dosage. No apparent phytotoxic effect was noted in any of the plants.

C. Insecticide Residue Determinations

1. Mobil MC-A-600. Samples of milk from cows that had been fed Coastal bermudagrass silage which had been sprayed with Mobil MC-A-600 at levels up to 32 ounces per acre were analyzed. No detectable residues were found. The concentration of Mobil MC-A-600 in bermudagrass silage that had been treated at the 32-ounce-per-acre dosage decreased from 63 ppm on the date the grass was ensiled to 34 ppm after 36 days in the silo.

2. Bomyl®. Analyses were made of samples of millet, corn, and Coastal bermudagrass from plots at Tifton, Ga., treated with emulsion sprays of Bomyl®. Millet treated with 4 ounces per acre contained residues of 0.63 ppm the day it was sprayed and less than 0.1 ppm one day after treatment. Millet treated with 8 ounces per acre contained residues of 0.16 ppm one day after treatment. Corn samples collected 2 days after treatment contained less than 0.1 ppm. Residues on Coastal bermudagrass from both levels of treatment were in excess of 1 ppm one day after treatment, but were less than 0.1 ppm 6 days after treatment.

3. Niagara NIA-10242. Residues of Niagara NIA-10242 on Coastal bermudagrass treated at the rate of 16 ounces per acre decreased from 43 ppm immediately after spraying to 2.1 ppm 14 days after spraying.

4. Malathion. At Bozeman, Mont., and Yakima, Wash., studies were made to compare residues of malathion applied to range grass at 2.5 ounces per acre as a solution in a light cracked-gas oil (1 gal per acre), a water solution (1 gal per acre), and a low-volume concentrate (1 pt per acre). The initial residues from the light cracked-gas oil solution, the water solution, and the low-volume concentrate, were 223, 177, and 160 ppm, respectively. Twenty-one days later these values had decreased to 34, 19, and 23.

D. Biological Control

1. Grasshoppers. In 1965, observations were continued in Arizona on natural enemies of grasshoppers. Parasitization by nemestrinid flies ranged up to 72% in some locations.

At Bozeman, Mont., efforts are being made to use microorganisms for control of grasshoppers. These include three protozoans and a virus.

Of the 4 pathogens, Nosema locustae (a sporozoan which infects the grasshopper fat bodies) has been used most extensively in laboratory and field studies. This organism was applied in the field under experimental conditions in 1964 and 1965. Although these applications have been successful in establishing the disease in the grasshopper populations, they have not been instrumental in causing detectable population reductions.

Another sporozoan, Nosema n. sp., has been isolated and described from grasshoppers. This organism infects the digestive tract, fat bodies, pericardium, gonads, and nervous system of the host insect. It completes its life cycle in 5 days, during which it induces the formation of tumors in the host. It is apparent that the relatively high pathogenicity of this organism is due to these tumors, which ultimately produce lesions in the digestive tract and cause the death of the host due to secondary bacterial septicemia.

Malamoeba locustae, an amoebic protozoan, infects the digestive tract epithelium and Malpighian tubules of grasshoppers. This results in decreased vitality and reduced fecundity in the host insect. The organism is a common problem in laboratory grasshopper cultures and studies are in progress to control the organism through the use of antibiotics. Triple sulfa has been effectively used for controlling the organism in infected specimens as well as preventing infections in young cultures.

During the past year a polyhedral virus was isolated from grasshoppers. This is the first instance of a virus being isolated from grasshoppers. This virus infects the fat bodies of grasshoppers which results in reduced fecundity and premature mortalities.

A grant was recently awarded to Montana State University to study the virus diseases that attack grasshoppers.

2. Alfalfa Weevil. In 1966, the alfalfa weevil continued to spread northward in Missouri, Illinois, and Ohio, and was found for the first time in Michigan. Parasitism of larvae by the 2 most widely established parasites, Bathyplectes curculionis and Tetrastichus incertus, during peak larval population in Maryland and New Jersey was low. Bathyplectes did not exceed 13% parasitism in any of the 20 survey fields until June when host populations were very low. Tetrastichus appeared commonly during June, as is normal. A bacterial disease of larvae was isolated in the fall of 1965. The isolate was highly pathogenic to larvae by injection, and slowly pathogenic when fed contaminated foliage. Larvae exhibiting the typical disease symptoms were collected commonly in the field throughout the spring of 1966.

A study, begun in the spring of 1963, to determine the amount and effect of parasitism on the alfalfa weevil, Hypera postica; in the area immediately east of the Rocky Mountains has been continued. Parasitism by B. curculionis in 1965 ranged from 31% in the Arkansas Valley (Kansas and Colorado) to 90% in the North Platte Valley (Nebraska and Wyoming). Weevil populations, although not economic, are increasing in the Arkansas Valley but are stable or decreasing in areas with higher rates of parasitism.

3. Egyptian Alfalfa Weevil. Collections of the Egyptain alfalfa weevil in areas where the larval parasite, T. incertus, was released in 1965, indicated that this parasite probably did not become established, and additional releases were made in 1966.

4. Spotted Alfalfa Aphid. Trioxys utilis was the only parasite of the spotted alfalfa aphid that was recovered in 1965 and 1966 in Arizona. No parasitized aphids were found in June but by August 2.4% were parasitized.

Systematic biweekly observations on the spotted alfalfa aphid and its natural enemies were continued until the end of 1965 in 4 alfalfa fields in the Salt River Valley of Arizona. In 1966, the leading predators of the

spotted alfalfa aphid in Arizona are Orius spp., Collops vittatus, and nabids. There was a 57% increase in total predators over 1964. Aphid mortality from fungus diseases was 18% early in December following a very rainy period, but it was not observed during the rest of the year.

5. Armyworms and Cutworms. At Baton Rouge, La., a study was undertaken to determine the possibility of using dissection for the determination of parasitism in two species of armyworms. Field collections of larvae of the armyworm and fall armyworm were divided into two lots. One lot was reared to determine parasitism, and the other lot dissected. Results with the fall armyworm were encouraging and percentages of parasitism by both methods were relatively close. In the case of Pseudaletia, however, nearly twice as many parasites were reared as were dissected.

Over a 5-year period in Louisiana, 17 species of armyworm parasites were identified. Although the overall percentage of parasites was very uniform from year to year (35 to 39%) the variation in the relative number of the various parasite species was great.

6. Rhodesgrass Scale. Studies were continued under a research contract with the Texas Experiment Station on mass producing and distributing Neodusmetia sangwani, a parasite of the Rhodesgrass scale. These tests have shown that as the number of female parasites was increased at each release point, the percentage of colony establishment increased. August and September was a better time for release of parasites than during the winter. For mass release of this parasite the method that appears most desirable is to collect grass from areas where the parasite is well established and place 10 to 15 stems in a paper box and make releases from an airplane at one box per square mile.

7. White-fringed Beetle. At Gulfport, Miss., microscopic examination of white-fringed beetle larvae that had been confined to dyed soil showed dye in the midgut and hindgut. This indicates that the larvae ingest some soil, and could ingest pathogens that might be present in the soil.

8. Grass Insects. At University Park, Pa., a Dryinid wasp was found parasitizing nymphs and adults of three species of leafhoppers and two species of plant hoppers collected from timothy and bromegrass. Parasitism ranged from 1 to 25%. Parasitized hosts had from 1 to 3 Dryinid larvae. These left the host and spun a small grayish white cocoon on blades of grass and trash. All reared and collected adult Dryinid wasps were apterous females. Adult females are predacious.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Spittlebugs. Although the female two-lined spittlebug gives off a pungent vanilla-like odor, workers at Tifton, Ga., determined that this odor was not a sex attractant, but acted more like a repellent.

2. Fall Armyworm. At Tifton, Ga., observations of the fall armyworm have revealed that crepuscular activity of the moths first involves congregation on host plants for feeding. After a period of feeding, the moths become quiescent for a time, then they often begin vibrating their wings before mating. Recordings on a sonagram of the wing vibrations of the roosting moths indicated the frequency was very low, in the 60-70 cps range. Sounds from magnetic speakers within this frequency range and directed into a cage of moths resulted in erratic results but a strong indication was obtained that moths were attracted to the sound.

3. Sweetclover Weevil. At Lincoln, Nebr., to investigate the attractiveness of coumarin to the sweetclover weevil, one square foot plots within an alfalfa field were treated by applying 200 mg of coumarin to the ground surface. Under the conditions of this test, coumarin was attractive to adult weevils as evidenced by their presence in the plots and by the fact that 15.4% of the alfalfa leaves in the treated areas had weevil feeding notches on them in comparison to 1.4% in equal areas of nearby untreated alfalfa.

4. Alfalfa weevil. In research conducted under a grant to Virginia Polytechnic Institute, 14 extracts from alfalfa were tested for attractiveness to the alfalfa weevil. A hot aqueous 2% NaCl extract was the most promising. Water extracts and ethanol extracts have also elicited some response.

5. Alfalfa Seed Chalcid. Studies conducted at the University of Wyoming under a research grant has shown that there may be chemosensory hairs on the alfalfa seed chalcid ovipositor which may influence ovipositional behavior. A total of 81 chemicals from the alfalfa plant have been tested and several have elicited an ovipositional response.

F. Evaluation of Equipment for Insect Detection and Control

1. Alfalfa Insects. Field research with liquid propane flamers was continued at Beltsville, Md., for control of the alfalfa weevil. Applications made in March have given control nearly equal to that obtained with a standard insecticide application of methoxychlor-malathion. Flaming stubble immediately after first harvest has also given good control without harm to the subsequent stand or yield.

G. Varietal Evaluation for Insect Resistance

1. Potato Leafhopper. In cooperation with the Crops Research Division, a technique developed at University Park, Pa., to screen alfalfa seedlings for resistance to meadow spittlebug, potato leafhopper, and alfalfa weevil, was used to screen two pools of alfalfa, each containing about 1130 plants. The best 90 plants were chosen from each pool and are being intercrossed.

At Lincoln, Nebr., a replicated alfalfa nursery of clones resistant, intermediate, and susceptible to the potato leafhopper was established in 1964

to study the relationship between leafhopper numbers, injury score (amount of yellowing), stage of growth, and changes in quality (protein, nitrate, carotene, dry matter, and fiber). One half of the nursery was treated weekly with insecticide in 1965. Protein content of both insecticide treated and untreated samples of the susceptible clone decreased with plant age. Total protein in the treated samples was, however, always as high or higher each time sampled. Protein content of the untreated intermediate clone increased with an increase of the injury score from 1 to 3 and then progressively decreased while the protein content of the treated samples of the same clone decreased evenly as plant age increased. Fiber content of untreated samples from both clones remained relatively constant with plant age. Carotene and nitrate content of the untreated and treated samples of both clones decreased with time. Carotene content of the treated samples was consistently higher than the untreated samples from both clones. Not much difference in the nitrate content was observed between the treated and untreated samples from both clones.

2. Alfalfa Weevil. Additional improvements have been made in laboratory testing techniques for screening for resistance to the alfalfa weevil at Beltsville, Md. Procedures and techniques are now fairly well standardized. Mass screening of seedling material in the cotyledon stage by exposure to adult feeding has proven effective in isolating promising material. Plants surviving this screening, and clonal material selected in the field, are then subjected in isolation to tests of (1) adult feeding on leaf disks, (2) larval survival and development, and (3) oviposition response. Significant differences have been found among entries for all three factors. Superior selections are being intercrossed in various ways in an attempt to intensify the level of resistance presently found.

3. Spotted Alfalfa Aphid and Pea Aphid. Testing of recently released commercial alfalfa varieties and promising experimentals composed by breeders of Arizona, California, and Nevada for resistance to biotypes ENT A and ENT B of the spotted alfalfa aphid shows that resistance is progressively improving in both public and private programs. Public varieties are still superior to private varieties in this regard but one private variety (Bonanza) ranked just behind the best public varieties.

In support of the alfalfa breeding programs of Arizona and California, 1300 seedlings highly resistant to the spotted alfalfa aphid were screened from populations of the experimental varieties SW-25, SW-39, and SW-40, all of which are of Sirsa origin. These seedlings are now being used to improve disease and insect resistance and agronomic quality of these varieties by reselection for other characters. Five hundred of these seedlings screened from SW-25 have been screened for pea aphid resistance at Tucson and 35 plants were selected for crossing and reselection among progeny.

Polycross seed of each of the 14 clones of experimental variety Nevada Syn X was screened for both spotted alfalfa aphid and pea aphid resistant plants. Ten progeny of each parent selected as highly resistant to both

aphids were returned to the breeder for a second polycrossing prior to rescreening.

Recent studies at Lincoln, Nebr., have shown that there is an interaction between four alfalfa clones and temperature in regard to resistance to the pea aphid and the spotted alfalfa aphid when the aphids were confined to the plants. Resistance breaks down as the temperature is lowered.

Eighty alfalfa plants selected in field nurseries for resistance to the potato leafhopper were tested for resistance to both the pea aphid and the spotted alfalfa aphid in the greenhouse. Of the 80, 18 were classified as resistant to both aphids or resistant to one and intermediate to the other.

Under a contract with Kansas State University good progress is being made in developing alfalfa varieties with resistance to two or more insects. Seed of one synthetic variety with resistance to pea aphid, spotted alfalfa aphid, and bacterial wilt is presently being increased in Oregon.

Work was continued under a long-term cooperative agreement jointly with the Crops Research Division and the Nevada Experiment Station to determine the biochemical nature of alfalfa resistance to the pea aphid and the spotted alfalfa aphid. The bioassay of extracted plant materials in artificial feeding devices has not been entirely successful, but it has been shown by P^{32} uptake in aphids that they feed more consistently on susceptible than resistant plants.

4. Alfalfa Seed Chalcid. At Mesa, Ariz., progeny tests on 14 plants resistant to the alfalfa seed chalcid showed that the level of resistance in the progeny was below that of the parents. This reduction in resistance was attributed to the introduction of foreign pollen from susceptible plants to the progeny during pollination.

5. Lygus Bugs. At Tucson, Ariz., no lygus bug resistant alfalfa varieties were found in a group of 116 tested.

At Manatttan, Kans., under a grant with Kansas State University, an attempt has been made to evaluate alfalfa in the seedling stage instead of in the blooming stage for resistance to the tarnish plant bug. Preliminary tests were inconclusive, but differences within and between varieties were obtained.

6. Sweetclover Aphid. Initially, results of studies at Lincoln, Nebr., on the inheritance of aphid resistance in sweetclover indicated only a single pair of genes. Additional data suggest the possibility of two pair of complementary genes governing aphid resistance.

7. Sweetclover Weevil. At Lincoln, Nebr., under a grant with the University of Nebraska, a bioassay method to help determine the factor causing resistance in Melilotus infesta to the sweetclover weevil has been

developed using sweetclover root disks processed by freeze drying. Water methanol extracts from M. infesta appear to cause a response from the weevil.

8. Grass Insects. At Tifton, Ga., 28 bermudagrasses were compared with Coastal bermudagrass for resistance to fall armyworm larvae. Three selections showed less feeding than the Coastal bermudagrass.

Emphasis is being given at Bozeman, Mont., to a study of grasshopper resistance in range grasses and legumes. Eight grasses and one legume have been compared for resistant qualities through two generations of the migratory grasshopper. Grasshoppers started on lettuce and transferred to the test plant during the fourth instar resulted in sexually mature individuals which laid eggs for the continuation of the study. The number of egg pods laid per female ranged from 6.3 to 12.7 for the parent generation and from 4.3 to 8.2 for the F_1 generation. The weight gain per male ranged from .012 to .072 g for the parent generation and from .002 to 0.68 g for the F_1 generation. The weight gain per female ranged from .030 to .115 g for the parent generation and from .015 to .125 g for the F_1 generation. It is concluded from these studies that the main mechanism of resistance is antibiosis. Two species of grass, blue bunch wheatgrass and green needlegrass, appear to be the most resistant to the feeding.

H. Insect Vectors of Diseases

1. Red Clover Virus. At University Park, Pa., red clover plots growing under cages which excluded insects showed much less clover virus and stands were more persistent than unprotected plots.

2. Sitona and Root Rot in Alfalfa. In cooperation with the Crops Research Division, a study was made at University Park, Pa., to determine the interrelationship of the clover root curculio and Fusarium wilt of alfalfa. Yield reduction in the first cutting was caused only by Fusarium wilt. Reductions in yield in the second and third cuttings were due to both Fusarium and clover root curculio. The fourth cutting was reduced only by the clover root curculio. Fusarium wilt was the greatest cause of dead plants but the curculio contributed significantly to the number of dead plants.

3. Legume Viruses. Research was continued in 1965-66 in Poland under PL 480 project, E21-ENT-9, on insect vectors of virus diseases of forage legumes. Six different strains of pea aphid transmitted yellow bean mosaic virus but the rate of transmission varied between strains. Both the green peach aphid and the pea aphid were able to transmit simultaneously the yellow bean mosaic and red clover vein mosaic viruses from red clover to crimson clover.

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AREA NO. 6. SOYBEAN AND PEANUT INSECTS

Problem. Soybeans and peanuts are severely damaged by several insect pests in the different areas where these crops are grown in the United States. The increasing concentration of acreage in soybeans and possibly the adaptation of native insects to this crop are resulting in more varied and more serious insect problems. Basic information is lacking on the biology of many of these pests and on the extent and nature of damage they cause to these crops. Such information is needed to serve as a foundation for the development of satisfactory control methods. Some insecticides, although highly effective in controlling insects on soybeans and peanuts, cannot be used because they leave harmful residues. Further, certain insects have developed resistance to insecticides that are currently recommended. For the immediate future, there should be continued effort to find insecticides that can be used safely and that give effective, economical control of all species of insects attacking these crops. For more desirable long-range solutions to the problems, more attention needs to be given to nonchemical control methods, with particular emphasis on insect-resistant crop varieties and biological control agents and the exploration of new chemical approaches such as attractants and repellents.

USDA AND COOPERATIVE PROGRAM

The Department has a limited program involving basic and applied research on insect problems of peanuts and soybeans directed toward developing efficient and economical control methods. The program is cooperative with State and Federal entomologists, agronomists, and chemists. Studies on soybean insects are conducted at Columbia, Mo., and on soybean and peanut insects at Tifton, Ga., in cooperation with the Missouri and Georgia Experiment Stations

A grant to the Oklahoma Experiment Station will provide information on varietal resistance of peanuts to thrips.

The Federal scientific effort devoted to research in this area totals 2.5 scientist man-years. Of this number 0.5 man-year is devoted to basic biology; 0.3 to insecticidal control; and 0.1 to biological control; 1.4 to varietal evaluation for insect resistance; 0.1 to insect vectors of diseases; and 0.1 to program leadership.

In addition, Federal support of research in this area conducted under grants provides a total of 0.4 scientist man-year on varietal resistance.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 7.4 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Soybean Insects. Studies at Columbia, Mo., indicated that, based on larval weight and rate of larval development, soybeans was a less desirable host for the corn earworm than cotton or tomatoes. First instar larvae of Heliothis zea were transferred to tomatoes, cotton, and soybeans grown in the greenhouse. Larval weights were recorded at intervals to determine differences in development on different hosts. Results indicated that larval weight was increased and pupation occurred earlier where larvae were reared on tomatoes. Lesser weights and later pupation occurred when the larvae developed on cotton and soybeans in that order.

At Columbia, Mo., the broadheaded bug, Coriscus pilosulus, has been reared continuously in the laboratory. A summary of the life history of this vector of yeast spot disease of soybeans is as follows: Egg incubation period 8 days, period from hatch to adulthood 27 days, preoviposition period 6.5 days, adult longevity 23.6 days. The egg viability averaged 76.8%. The percent mortality which occurred in each of the instars was: first, 4.9%; second, 15.4%; third, 21.6%; fourth, 23.4%; and fifth, 19.75%. Adult longevity was 23.6 days. The sex ratio of 89 adults was 40.45% males and 59.55% females.

2. Peanut Insects. Observations at Tifton, Ga., on the activities of the lesser cornstalk borer on peanuts indicated that larvae upon hatching, either fed on flower axils and entunneled in webbing or fed on leaves at the base of the plant and entunneled in combined webbing and soil. Feeding in flower axils continued only until the larvae reached the third or fourth instar, when they abandoned this location and migrated to the soil level to begin feeding. No plants were killed due to the lesser cornstalk borer and larvae were not found within the pods. It appears that the larva may be largely a defoliator, especially of basal leaves of peanut plants.

B. Insecticidal Control

1. Fall Armyworm. At Tifton, Ga., 6 insecticides were field-screened on soybean foliage at 4, 8, and 16 ounces per acre to determine their toxicity to 4-day-old fall armyworm larvae. The insecticide Schering 34615 gave 88% control at 16 ounces per acre and the 4-and 8-ounce rates gave good control through the fourth day. General Chemicals GC-6506 gave good control, one day after treatment, but poor control on the fourth day. The insecticide Geigy GS-13005 at 16 ounces per acre was effective through one day, but gave only fair control on the second day. Niagara NIA-10242 gave excellent control through the second day at 8 and 16 ounces per acre, but only through the first day at 4 ounces per acre.

2. Thrips. At Columbia, Mo., Azodrin at 0.6 pounds per acre gave excellent control of thrips on soybeans. A mixture of DDT (1.5 lb) and parathion (0.25 lb) gave good initial control, but was not effective after 6 days.

C. Varietal Evaluation for Insect Resistance

1. Soybean Insects. At Columbia, Mo., over 525 soybean varieties, principally plant introductions, were evaluated for resistance to the green stink bug Acrosternum hilare in a large field cage measuring 100' long 60' wide and 8' high. Differential damage between varieties has been recorded but no highly resistant varieties have been found.

2. Peanut Insects. At Tifton, Ga., advanced peanut lines were evaluated for resistance to an artificial infestation of the lesser cornstalk borer and natural infestations of the velvet bean caterpillar, the fall armyworm, the corn earworm, and thrips. Four varieties (Runner check, Ga. 186-38, Florida 416, and Florigiant) were significantly low in foliar ragging. A significant association existed between levels of foliar ragging and yield among lines. Five varieties (NC-2, Argentine, V.B. 67, Starr, G.E. 652) showed some resistance to thrips.

A grant was recently awarded to the Oklahoma Experiment Station to evaluate peanut varieties for resistance to thrips.

D. Insect Vectors of Diseases

1. Soybean Insects. The organism, Nematospora coryli, has been shown to be harbored within the salivary system of the green stink bug. Isolations of this organism have been made repeatedly from sterilely dissected salivary receptacles and salivary pump of the insect. The salivary receptacles and stylets of this insect were found to harbor the yeast 35 and 55% of the time, respectively. The insects had a higher frequency of occurrence of the organism as the season progressed from July to September. Heretofore it was believed that the disease was transmitted only incidentally and by external contamination of the insect.

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AREA NO. 7. CORN, SORGHUM AND SMALL GRAIN INSECTS

Problem. Many species of insects cause losses amounting to millions of dollars annually to corn, sorghum, and small grains. It is estimated that 25 species of insects cause an annual loss of $900 million to corn alone. The European corn borer and corn earworm are two of the most destructive insects in the country, and corn rootworms are serious pests of corn. Armyworms attack corn and small grains. In certain years the greenbug causes widespread losses to wheat, barley, and oats in the Central and Southeastern States, and the Hessian fly and wheat stem sawfly annually damage the wheat crop in certain areas. The cereal leaf beetle, first identified in the United States in 1962 from Berrien County, Mich., now occurs in many counties in Michigan, Indiana, and Ohio, and is a threat of unknown proportion to small grain crops. Such examples of the destructiveness of insects to corn, sorghum, and small grains point up the need for extensive research that will lead to the development of adequate means for the control of these important crop pests. Progress has been made toward the solution of some of the insect problems encountered in the production of grain crops but more effective, more economical, and safer insect control measures are needed. Research is essential to find insecticides that can be applied to grain crops, that will not leave residues harmful to animals consuming the feed, that will not be a hazard in milk, and meat, and that will not be detrimental to beneficial insects or to fish and wildlife. The appearance of resistance to certain insecticides in several grain insect pests stresses the need for basic information to overcome this problem. Additional emphasis should be placed on research to develop crop varieties resistant to insects and on biological and cultural control methods. New approaches to insect control, such as sterilization techniques and attractants, require expanded investigation. Research is also needed on insect vectors and the role they play in the dissemination of important plant diseases. The heavy losses in oats, wheat, and barley due to barley yellow dwarf virus, and in corn due to maize dwarf mosaic and corn stunt recently found in several North Central and Southern States, indicate the importance of research in this field.

USDA AND COOPERATIVE PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on Hessian fly at Lafayette, Ind., and Manhattan, Kans.; cereal leaf beetle at Lafayette, Ind., and East Lansing, Mich.; aphids and

mites attacking small grains at Stillwater, Okla., Brookings, S. Dak., and Tifton, Ga.; wheat stem sawfly at Fargo, N. Dak., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and Lafayette, Ind.; fall armyworm, pink scavenger caterpillar, and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. Dak., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. Dak.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm, and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and insect transmission of grain diseases at Manhattan, Kans., State College, Miss., and Brookings, S. Dak. Research to evaluate improved equipment for application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. Work on corn rootworms is being conducted at Brookings, S. Dak. Additional research is being conducted under ARS contracts and grants on the biology and control of the cereal leaf beetle with Michigan, Indiana, and Ohio Experiment Stations, soil insects attacking corn with the University of Nebraska, and vectors of corn stunt virus with Mississippi State College, nature of resistance of corn to the European corn borer with Iowa State University, and insect communication in the infrared region with Michigan University, Ann Arbor, Mich., transmission of viruses causing stunting of corn, with Missouri University, ecological factors affecting efficiency of Trichogramma spp. with Louisiana State University.

The Federal scientific effort devoted to research in this area totals 42.3 scientist man-years. Of this number 10.8 is devoted to basic biology, physiology, and nutrition; 3.5 to insecticidal and cultural control; 1.8 to insecticide residue determinations; 4.1 to biological control; 2.9 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 15.7 to varietal evaluation for insect resistance; 1.8 to insect vectors of diseases; and 1.4 to program leadership.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations." A P.L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligypona pellucida (F.) and the Nature of Injuries Caused by this and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" is underway at the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland. Another P.L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of the Disease" is being conducted at the Hebrew University, Rehovoth, Israel. A7-ENT-25 in India is concerned with "Research on Insect Pests of Maize with Special Reference to Stalk Borers." Projects A7-ENT-31 in India, "A Study of the Host Plant-Vectors and Host Plant-Virus Relationships in the Rough Dwarf Virus Disease of Maize, in Order to Develop Efficient Methods for the Control of the Disease," and E21-ENT-14, in Poland, "Studies Regarding the Bionomics, Economic Importance and Natural Control Factors Affecting Oulema Species/Cereal Leaf Beetle in Poland," and E30-ENT-3 in Yugoslavia on "Parasites, Predators, and Pathogenic Organisms Study of the Cereal Leaf

Beetle, Resistance Investigation of Domestic and Foreign Small Grain Varieties to Oulema melanopa," are also being conducted.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 39.2 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Corn Insects. Average seasonal populations of the western corn rootworm at Brookings, S.Dak., dropped to a low of 1.0 adults per 100 plants in 1965. In contrast northern corn rootworm populations increased sharply to 522. adults per 100 plants for the season. Similar changes in the northern and western corn rootworm adult population ratios have been reported in State survey reports from Minnesota and Iowa.

Laboratory and field studies have shown that contrary to common believe the corn rootworms can use plants other than corn for larval development. Tests in field cages indicated that green and yellow foxtail grass, Minter wheat, Omugi barley, Oahe intermediate wheatgrass, in addition to corn supported rootworm development to the adult stage. None supported as large a population as corn. Adult western corn rootworms produced viable eggs when reared as larvae on wheat, barley, and green foxtail grass. Northern corn rootworm adults laid viable eggs when they were reared as larvae on wheat and the southern corn rootworm produced viable eggs when reared on wheat, barley, and yellow foxtail grass.

Corn plots with an average of less than 1% of the plants damaged by corn rootworms had a yield of 115 bushels per acre. Plots with 60% of the plants showing damage had a yield of 88 bushels per acre, or a 23% yield loss due to corn rootworm.

Laboratory studies indicate that fertile backcrosses are possible with parental stocks. F_3 hybrid beetles (P_1= WCR ♂ x NCR ♀) were backcrossed to northern (NCR) and western (WCR) corn rootworms. Eggs collected from the 4 reciprocal crosses were incubated and only the eggs from F_3 hybrid ♀ x NCR ♂ failed to hatch. Adults were reared from eggs laid by F_3 hybrid ♀ x WCR ♂, WCR ♀ x F_3 hybrid ♂, and from NCR ♀ x F_3 hybrid ♂. All F_4 adults appear morphologically similar to WCR.

Ecological data on the corn borer population in Boone County, Iowa, showed an early spring population of 3,417 borers per acre, midsummer borer population of 2,538 borers per acre, second brood pre-harvest population, 4,313 borers per acre, and after harvest survey of borers going into hibernation of 1,625 borers per acre. Light trap catches at Ankeny Farm indicated two complete generations of corn borers with a partial third.

Field experiment investigations on the biotypes of the European corn borer indicated incidence of diapause among the F_1 generations was the best criterion for separating one biotype from another. Borer cultures from Minnesota had a higher percent diapause than those from Missouri, with those from Iowa intermediate between the two. No biotypes capable of damaging previously resistant crop varieties were found.

Tests conducted at Ankeny, Iowa, show that pollen shedding at time of infestation had a profound effect in increasing second brood larval establishment on susceptible inbreds, but very little or no effect on resistant inbreds.

Greenhouse studies show that 1/4 to 1/3 of the corn borer larvae hatching from eggs laid on the corn plant migrate off the plant. No differential in larval migration from susceptible inbred WF9 and resistant inbred C.I.31A was observed. There was a wide differential in larval survival after egg hatch on susceptible and resistant inbreds.

Diet improvement studies provided a laboratory rearing diet which is an improvement over the diet used for the past several years. Wheat germ has been substituted for ground corn leaf, and changes made in vitamin and salt content. Larvae reared on the new diet are more uniform in size and require less of it for complete development.

A study of spermiogenesis in corn borer larvae showed that testis volume increases throughout larval and early pupal life, then with emergence of the adult insect, it gradually decreases. The testis of third instar larvae contains essentially only spermatogonial and primary spermatocytal cysts; secondary spermatocytal cysts predominate in the 4th instar larva; spermalidal cysts are at peak numbers in early pupal life; spermatozoa appear in full grown larvae and predominate in late pupal testes; when the insect reaches adulthood it contains its full complement of sperm.

Chromic oxide, added to the dry matter of test diets fed to European corn borer larvae, provided colorimetric method for measuring diet consumption and utilization during growth. These tests showed that growing corn borer larvae may consume up to 40 mg of food per day and utilize as much as 52% of it. The larvae utilize their food most effectively during the 3rd and 4th instars - first and 5th instar larvae being the least efficient.

In Mississippi in 1965, 70% of the ears in all corn fields were infested with the corn earworm, 89% of the ears were infested with pink scavenger caterpillar, and 18.6% with rice weevil. Southwestern corn borer damage to dent corn in Mississippi continues to be a serious problem. The percentage fields infested increased from 66.2% in 1964 to 78.4% in 1965. The southwestern corn borer spread to 2 additional uninfested counties in Mississippi, 2 in Alabama, and 2 in Tennessee.

At Tifton, Ga., a commercially available food packaging machine was modified to mass rear the fall armyworm. The machine fills 1 ounce plastic containers with artificial diet, dispenses a larva on the diet, and caps the container in one continuous operation. The rate may be varied between 2,000 and 4,500 containers per hour. One thousand pupae can be produced with this machine at a cost of $14.60, adults for $16.50, and larvae $9.20.

Experiments at Tifton indicate that the simplex in the male fall armyworm reproductive system may be used to determine if the males had mated. In the unmated condition the simplex is filled with a substance of dark coloration, whereas in the mated condition the simplex is transparent.

At Tifton tests indicated that mating in the corn earworm increased when the surface of the insect cages was lined with low emissivity aluminum foil and when a corn plant was added to the cages. Highest mating was obtained when both factors were combined (83.5%). Higher mating was found in foil-lined cages without plants than was found in unlined cages with plants.

Tests conducted at Tifton, Ga., showed that near infrared had a highly stimulating effect on flight of the Indian meal moth. After the moth's eyes had been day conditioned ("gated") by a low intensity 5200 Å visible light source, the moths flew continuously until death - at 48 hours. When infrared was used in conjunction with light of the ultraviolet region, infrared had no stimulating effect on moth flight.

2. Small Grain and Sorghum Insects. Surveys conducted during the 1965-66 crop year indicate approximately 10 million acres of Hessian fly resistant varieties, developed through the cooperative efforts of USDA and Experiment Station personnel, were grown in more than 24 States. This represents an increase over last year of 1-1/2 million acres.

A new Hessian fly resistant soft red winter wheat, Benhur, was developed and released in Indiana. This wheat, besides being resistant to the major wheat diseases, is resistant to the new race of Hessian fly (Race B) threatening the wheat crop in southern Indiana. Benhur covers the H_c gene for resistance and protects the wheat from Races A and B.

Hessian fly populations are building up in susceptible wheat varieties grown in Michigan. Samples from 111 certified wheat fields in Michigan showed 82% of the fields to be infested with Hessian fly with an average infestation of 16.9% for those wheats having no Hessian fly resistance, and only 2.6% for those wheats having fly resistance. Hessian fly resistant wheats were slightly infested in those counties bordering Indiana, due to a Race B buildup resulting from large acreages of Monon wheat being grown in the area.

Investigations conducted at East Lansing, Mich., indicate that oviposition and viability of eggs of the cereal leaf beetle might be improved by use of a shorter cage with a higher relative humidity and fewer insects per cage.

These studies also indicate that a sex ratio weighted possibly as high as 4:1 in favor of the female will produce a greater number of eggs. In several instances females have laid up to 400 eggs each and in one case one female had laid over 900 eggs in a five-month period.

Studies on the life stages of the cereal leaf beetle indicate that the two main factors affecting reproductive activity of the cereal leaf beetle are temperature and photoperiod. Optimum conditions for the maximum reproduction in this insect are 80° F, 16 hours of light, and 50-70% relative humidity. Beetles raised under 12, 20, and 24-hour light periods failed to produce eggs. Any group of newly-emerged adults held under optimum conditions is capable of egg production after a period of 25 to 30 days. An individual female is capable of producing up to 1,251 eggs during her life span and up to 28 eggs a day.

An assay method suitable for determining degrees of induction or termination of diapause in the cereal leaf beetle was developed. Serial sections of the brain and related glands were made of pre-, post-, and diapause beetles, both male and female, and stained, using paraldehyde fuchsin neural-secretory techniques. Differences were observed between pre- and diapause beetles versus post-diapause beetles. Both median neural-secretory cells and the corpora allata appeared to be active in secretory granules in the post-diapause condition.

Sorghum midge infestations in Oklahoma and the Plainview-Lubbock Area of Texas were light in 1965 - causing little or no damage. Observations have indicated that sorghum planted at "normal" planting dates and blooming in late July or early August, will escape damage from the midge.

In greenhouse tests at Stillwater, Okla., heavy infestations of the English grain aphid caused plant stunting and weight losses, ranging from 58% in Will barley to 89% in Cimarron oats.

Rearing tests conducted in plant growth chambers having day-night high-low temperature values of 60-35, 70-45, 80-55, and 90-65 degrees F, respectively, indicated that length of the reproductive period in days was inversely proportional to the temperatures. Mean temperatures of 50, 40, 36, and 34° F, progenies of 12 greenbugs in each chamber were 263, 559, 737, and 886. Reproduction began 27, 12, 9, and 8 days after start of the experiment in the respective temperature programmed chambers.

In tests conducted at Brookings, S. Dak., color had a definite effect on reproduction and survival of cereal aphids. The four most common cereal aphids in South Dakota, Macrosiphum avenae, Rhopalosiphum padi, R. maidis, and Schizaphis graminum were fed artificially through Parafilm membranes under different colored filters for a period of 10 days. Responses to specific colors differed with species, but in general green and orange filters resulted in most favorable survival and reproduction. It was also shown that variable light intensity was not involved in aphid response to

colored filters. Color preference tests with these same aphids indicated that adult apterae and nymphs of R. padi and nymphs of R. maidis preferred green over yellow, red, or blue. Apterae of R. maidis and apterae and nymphs of M. avenae and S. graminum preferred yellow.

Five species of false wireworms, Eleodes opacus, E. hispilabris, E. extricata, and Embaphian muricatum, and Eleodes suturalis, have been successfully reared in the laboratory at Brookings, S. Dak. Seeds most preferred for food were alfalfa, hullers barley, flax, forage sorghum, hullers oats, rye, and wheat.

A portable, self-powered, vacuum insect collector was used to collect adult sawflies in a heavily infested field of wheat at Minot, N. Dak. Adults collected were used to supplement field infested wheats in experimental plots. Sawflies collected by this method were subjected to an air flow of high velocity but little adult damage was observed.

In studies conducted under a grant at Purdue University on the behavior of the cereal leaf beetle as affected by climatic factors, it was found that the early summer and fall dormancy of the adult beetle can be interrupted by subjecting the beetles to high sublethal temperature. This treatment has resulted in good production of viable eggs from adult seasonal forms that normally will not produce eggs.

Studies were conducted under P.L. 480 project, E21-ENT-14, Poland, to develop survey methods for measuring distribution and damage of the cereal leaf beetle.

3. Other Insects. Aedes aegypti, when released in a cross-box composed of five compartments, preferred to rest on a surface that was highly infrared reflective.

When released in a room with two CDC miniature light traps, one radiating white light and the other infrared, the majority of mosquitoes collected were taken in the infrared trap. When released in total darkness, the mosquitoes were attracted to an infrared trap, indicating an ability to locate an infrared source. Blood-fed females and mated mosquitoes of both sexes appeared less attracted to infrared than when unmated or honey-fed.

B. Insecticidal and Cultural Control

1. Corn Insects. Twenty-two insecticides in granular formulation were field-tested against first-generation European corn borer larvae, and 23 were tested against second-generation borers at Ankeny, Iowa. Niagara NIA-10242 was an outstanding compound for control. Eleven gave control equal to or superior to DDT in these tests.

Spray formulations, field tested, consisted of 9 and 8 insecticides for first and second generation tests, respectively. Niagara NIA-10242 was

again outstanding for control. Azodrin, American Cyanamid CL-47470, and endrin were equal to or superior to DDT in these tests.

American Cyanamid CL-47470, applied to the soil at time of planting as a systemic insecticide gave satisfactory control for 30 to 40 days. Low volume application of malathion by air gave no control.

In Mississippi two weekly applications of Niagara NIA-10242 at 1.0 pound per acre for second generation southwestern corn borer and two for third generation gave 73.3% control.

At Tifton, experimental chemicals were evaluated in the field for control of the corn earworm and the fall armyworm attacking sweet corn. Five applications of each material was applied during ear development. Insect control was compared to that obtained with a DDT standard. Of the chemicals tested, only Azodrin was significantly better than DDT. Niagara NIA-10242, Mobil M-CA-600, and Shell SD-7438 gave control equal to the DDT standard.

Tests conducted on varieties of sweet corn, with varying degrees of corn earworm resistance, indicated that very little additional control could be obtained by applying DDT to varieties that were resistant to corn earworm attack. A significant increase in control was obtained by applying DDT to susceptible varieties.

The effect of crop removal on oviposition of the northern and western corn rootworms was investigated at Yankton, S. Dak. Corn rootworm egg laying patterns were determined by egg and larval samples, larval damage, and yield loss. Treatments where corn was removed as silage by September 27 showed very little rootworm damage. Where corn was not removed, severe lodging occurred the following year and yield was reduced 23%.

The effect of fall or spring plowing on corn rootworm populations was evaluated. No significant differences were found in plant height or plant population due to plowing treatments. Significantly more corn rootworm larvae and damage were noted in the fall-plowed treatment. No differences in yield were found, indicating that the rootworm damage tended to cancel out the expected yield advantage following fall plowing.

An aldrin resistant strain of southern corn rootworm has been isolated in the laboratory at Brookings, S. Dak., by insecticide treatment of a susceptible strain. The survivors of this treatment are being maintained as a separate culture. Preliminary data indicate that aldrin resistance in this insect could be a single gene recessive character.

2. Small Grain Insects. Tests were continued at Stillwater, Okla., to study the phytotoxic effect of insecticides on sorghums. Methyl parathion and Bidrin applied to 12 grain sorghum hybrids and breeding lines as a spray caused considerable burning. Ethion, diazinon, and carbaryl wettable powder caused no injury. Hybrids RS 610 and RS 626 and entries y-15 and y-16 (both having yellow endosperm) were not injured by any of the insecticides.

Exploratory tests indicate that it is possible to test grain sorghums for insecticide phytotoxicity in a greenhouse at an early stage of plant growth and in a shorter period of time than is required in the field. Microscope slides of leaf sections made from phytotoxicity-susceptible and resistant plants showed the effects of the phytotoxic action in the former. Damaged plants showed (1) disintegration of the chloroplasts, (2) clogging of xylem and phloem tissues (clogging material not yet identified), and (3) shrinkage of the cell walls. In Bidrin-sprayed plants the larger vascular bundles are affected first, later, the smaller ones. The reaction is just the opposite for plants sprayed with methyl parathion. There was no phytotoxicity when plants were sprayed with diazinon.

In Montana oxydemetonmethyl as a foliar spray applied at the rate of 2 pounds per acre with an additive, dimethyl sulfoxide gave 97% control of the wheat stem sawfly. Heptachlor applied as a foliar spray gave 56% control, and oxydemetonmethyl without sulfoxide 13%.

C. Insecticide Residue Determinations

1. Corn Insects. At Tifton rainfall produced a marked reduction in DDT residues on sweet corn. When one inch of artificial rain was applied at the rate of 0.5 inch and 2 inches per hour there was a 34% and 45% decline, respectively, in DDT residue. A second inch applied at the same rates decreased the deposits another 30% and 25%, respectively.

Gas chromatographic methods of analyzing for the chemosterilants, tepa, metepa, methiotepa, hempa, and apholate, were developed by chemists at Tifton, Ga. The methods employ the Malpar flame photometric detector and are sensitive to about 0.1 nanogram.

Studies were conducted at Tifton on the persistence of the chemosterilant, tepa, in fall armyworm moths. Both sexes were fed 0.3% tepa in 10% aqueous sucrose. After ingesting up to 100 µg to tepa per moth the insects were held in the laboratory under conditions of controlled temperature and humidity. Within 24 hours over 90% of the tepa had disappeared from the moths; over 95% was gone within 48 hours. Only 1 µg of tepa per insect was recovered from the feces after 48 hours.

Chemists at Tifton have developed gas chromatographic techniques for analyzing residues of Azodrin and Bidrin in raw extracts of sweet corn using a Melpar flame photometric detector. Residues as low as 2 ppb were detected without appreciable interference from the corn extract. A technique was also developed for analyzing residues of Imidoxan and Imidan in corn silage and in sweet corn at levels of 2 ppb for Imidan and 4 ppb for Imidozan.

D. Biological Control

1. Corn Insects. The microbial insecticide, Bacillus thuringiensis, in capsule, granule, and emulsifiable formulations gave excellent control of the European corn borer at Ankeny, Iowa. Laboratory studies with the bacterium showed that both the spore and crystalline inclusion are necessary to kill the borers. These also showed that a viable spore count is not sufficient standardization on which to base a "control" recommendation.

Further evidence of the importance of the borer infecting protozoan, Perezia pyraustae, in corn borer population reductions was noted in Boone County, Iowa, this spring. Field collections of borers showed an incidence of 50% infection at the mid-March survey and dropped to 16% at the May 1 survey. During this same period the borer population dropped from approximately 3,000 larvae per acre to 900 larvae per acre, indicating that the infected borers were less able to survive the climatic and agronomic changes which occurred during this 6-week period.

At Tifton, Ga., 5 generations of the egg parasite, Trichogramma, were reared on fall armyworm eggs sterilized with tepa without any decline in the parasite culture.

Additional information was obtained on the life history of Drino munda, introduced from India, and previously reported as Drino imbrebis, a tachinid parasite of the corn earworm. D. munda can successfully parasitize both the corn earworm and the fall armyworm. However, it requires almost 4 days longer to complete its life cycle on the fall armyworm than on the corn earworm.

Preliminary results on the effects of temperature and dosage on the pathogenicity of the fall armyworm nuclear-polyhedrosis virus indicated an increase in total mortality in the larvae held at 22-25° C. rather than higher temperatures.

2. Small Grain and Sorghum Insects. Field releases involving approximately 5,000 adult cereal leaf beetle egg parasites, Anaphes sp. have been made in Michigan. Recovery of parasites has been successful with approximately 30% of the eggs examined being parasitized.

Five hundred adults of the wheat stem sawfly parasite, Collyria calcitrator were released at Conrad, Mont., in 1965. One adult was recovered in 1966. Field observations and rearing of insects from collected stubble indicates that populations of the native parasite, Bracon lissogaster are building up slowly in cultivated wheat in Montana.

Tests conducted on parasite activity against the wheat stem sawfly at Fargo, N. Dak., showed that susceptible wheat varieties had the highest number of sawflies parasitized by B. cephi. Similarly, higher sawfly

infestation levels had higher numbers of parasitized sawflies. Sawfly larvae in plots of both susceptible and resistant varieties with low infestation levels were also parasitized indicating this parasite has a keen host-searching ability. These tests provided results which support the conclusion that since the number of parasitized sawfly larvae is a function of the number of sawfly larvae in a given area, the use of a wheat variety highly sawfly resistant would reduce parasite numbers materially.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. At Tifton, Ga., experimental chemosterilant compounds, ENT 51253, 50990-a, and 51028-a, were equally effective as tepa in sterilizing the fall armyworm moth. However, sterile males produced with chemosterilants were not as competitive for females as untreated males; competiveness being reduced by as much as 45% in moths sterilized with 45 µg. One hundred percent sterility was achieved when males or females of fall armyworm and corn borer moths were forced to walk over a felt pad saturated with a 10% sucrose solution of 0.3 to 0.15% tepa. This technique for sterilizing moths will be used in conjunction with light traps to trap, sterilize, and release moths back into their wild environments.

Sex pheromones of fall armyworm, Spodoptera frugiperda, corn earworm, Heliothis zea, and true armyworm, Pseudaletia unipuncta, have been found within the last abdominal segment of virgin, laboratory-reared female moths. Purified extracts of fall armyworm and of corn earworm elicited typical sexual reactivity in the virgin male of 3 species of looper, i.e., Trichoplusia ni, Pseudoplusia includens, and Rachiplusia ou. There is some possibility that this activity is due to the presence of impurities.

An insect feeding device utilizing a felt wick impregnated with the chemosterilant, tepa 0.15% and aqueous sucrose 2% has been developed at Tifton, Ga., for use in conjunction with light traps to sterilize moths in their natural habitat. Analysis for tepa at 1, 2, 3, and 5 day intervals indicate that amount of tepa on the wick diminished 20% during the first 24 hours, 53% by the end of the second day, and 86% by the end of the third day.

Preliminary tests indicated that the chemosterilant, apholate, was more effective in sterilizing the southern corn rootworm than metepa or tepa. Females treated with 50 ppm apholate mated with untreated males laid 281 eggs with 38% hatch; untreated females with treated males, 140 eggs with a 4% hatch; both sexes treated 55 eggs with 1.2% hatch. Beetles treated with 100 ppm apholate averaged fewer eggs per female.

Studies on the irradiation of diapausing corn borer larvae indicate that 4000 or 5000 roentgens will sterilize corn borer males, and reduce female egg production and hatch to near zero. Irradiated larvae pupated normally and emerged as apparently normal moths.

A procedure for purification of the sex pheromone of the female European corn borer adult has been developed at Ankeny, Iowa. Purification procedures involved extraction of the substance from the female moth with 1,2-dichloroethane followed by precipitation of inactive lipids at -70° C in solvents of increasing polarity, followed by column chromatography on silica gel and final purification by gas-liquid chromatography. Sixty thousand female moths are now being processed in an effort to obtain a sample of the sex pheromone of sufficient size to allow chemical characterization of the compound.

Male sterilization of the European corn borer was accomplished by feeding 7-day-old larvae tepa-treated media. Eight other compounds representing the different chemicals that have shown promise in other sterilization programs were evaluated, but were not effecitve.

In studies conducted under a grant at Ohio State University on microbiology and pathologies of Oulema melanopa, it was found the fat body structure of immature developmental stages can be used as a guide for detecting and recognizing new viruses infecting Coleoptera.

2. Small Grain Insects. Apholate was evaluated as a chemosterilant for the cereal leaf beeltes. Concentrations above 0.25% suppressed oviposition, and caused mortality of 80%. At 0.10% concentration, oviposition did not occur but mortality was reduced. Concentrations of 0.05% did not prevent oviposition and eggs were not viable. Eggs treated with lower apholate concentrations showed varying degrees of viability.

Eggs of the cereal leaf beetle treated with 1,00, 2,000, 4,000, 8,000, and 16,000 rads. failed to hatch. Hatching, larval survival, pupation, and adult development were normal when given a 1,000 rad. treatment just prior to hatching.

When newly emerged and third and fourth instar larvae of the cereal leaf beetle were irradiated, all levels of treatment above 1,000 rads. resulted in high larval mortality in all cases. At the 1,000 rad. level, there was some mortality but not significantly different from the controls.

Adult emergence of cereal leaf beetle was significantly decreased by irradiation with 1,000, 2,000, 4,000, 8,000, and 16,000 rads. One hundred percent mortality occurred at the 16,000 rad. level.

Four hundred and thirty-one chemical lures were evaluated as attractants for the cereal leaf beetle under field conditions. Twenty-five caused a response in the beetle. During the winter of 1965-66 an additional 200-300 synthetic materials were evaluated under laboratory conditions. None of the lures elicited a response.

Plant extracts prepared from seedlings of barley, oats, wheat, and corn during 1965 using various combinations of solvents and preparation

techniques failed to elicit a detectable response when exposed to adult cereal leaf beetles. Exposure of various populations of adult cereal leaf beetles in field cages during 1966 spring-adult field tests again has failed to indicate any presence of a pheromone.

An olfactometer suitable for testing attractants and repellants on soil insects was developed. The use of this device revealed that a chemical(s) produced by germinating wheat attracts larvae of Eleodes suturalis.

Studies on the effects of gamma-ray irradiation of non-diapausing wheat stem sawfly larvae in wheat stubble continued at Fargo, N. Dak. Sawfly larvae were exposed to total doses of 1,000, 2,000, 3,000, 4,000, and 5,000 rad from a Cobalt 60 source. Adult sawfly emergence at radiation levels of 1,000 and 2,000 rad was comparable to that of the non-irradiated samples. Adult emergence was greatly reduced at the 3,000, 4,000, or 5,000 rad levels.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. At Tifton, Ga., conventional insecticides applied every day gave better corn earworm control than insecticides applied every other day or every third day. Applications on an alternate day schedule were significantly better than applications made every third day.

Agricultural engineers and entomologists at Tifton have developed a tractor-mounted system for applying insecticides, either as technical or concentrated formulation, at extremely low volumes. One system is capable of applying the toxicant at rates as low as 1 pint per acre. The other system will apply toxicants as low as 1 quart per acre.

At Brookings, S. Dak., colored neon trap lights set up in a corn field indicated that certain shades of red and blue were more attractive to both western and northern corn rootworms than were others. However, corn was more attractive to the insects than were the lights. It was noted that while the sex ratio for both species was about 50:50, 97.6% of the western and 90.1% of the northern corn rootworms attracted to the lights were males.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. A cyclic hydroxamate (DIMBOA), a constituent of corn tissues, was found to be a chemical factor in the resistance of corn to the European corn borer. Resistant lines of corn produce 10 times more DIMBOA than do susceptible. In bioassay tests the compound inhibited larval development and caused a 50% mortality. Surviving larvae complete development to the adult form with no apparent morphological abnormalities. The biological activity of DIMBOA is sufficient to explain a large degree of the resistance expressed in the field by borer-resistant inbred lines of corn.

Conclusive spectroscopic evidence has shown that a second cyclic hydroxamate is to be found in corn tissue. Structurally, the second cyclic hydroxamate is very similar to DIMBOA and it is expected that the substance will possess biological properties similar to DIMBOA. Analyses have shown that this newly found compound exists at higher concentrations in the more resistant lines of corn.

Tests conducted at Ankeny, Iowa, with a group of 36 hybrids, some new releases and some old, indicated that factors other than leaf feeding resistance, i.e., sheath or stalk resistance and tolerance, are effective in some hybrids in reducing yield losses because of first-brood corn borer stress.

Genetic studies on the use of reciprocal translocations to determine chromosome arms involved in resistance of C.I.31A and B49 to a first brood infestation shows that C.I.31A carries genes for resistance on the short arms of chromosomes 1, 2, and 4, and in the long arms of chromosomes 4 and 6. B49 carries genes for resistance on the short arms of chromosomes 1, 2, and 4, and on the long arms of chromosomes 4, 6, and 8.

In tests at Wooster, Ohio, 8 of 18 inbred lines that indicated resistance or tolerance to the newly discovered virus maize dwarf mosaic also indicated some degree of resistance to a first-brood corn borer infestation.

Inbred GE 315 was the most resistant to southwestern corn borer of 5 inbred lines tested in all possible single cross combinations at State College, Miss. In another single cross test involving 8 inbred lines, Mp315 and Mp337 showed significant resistance to southwestern corn borer.

Resistance studies at Tifton, Ga., indicate that the husk, silks, and kernels all contribute to the amount of feeding (resistance) in an inbred to corn earworm. The factor(s) involved varies with each inbred. For example, inbred 166 had good husk resistance, inbred 245 silk resistance; inbred F-6, husk, silk, and kernels resistance. Pollination of silks increased larval survival.

At Tifton, Ga., 32 corn lines from South and Central America and 20 sweet corn lines were screened in the greenhouse for leaf damage by fall armyworm larvae. Lines showing some resistance were Zapalote Chico, Zapalote Grande, and Antiqua 2-D. In general, sweet corn showed more resistance than dents but further tests are needed to confirm this.

Studies were conducted on the utilization of diets by third instar fall armyworm and corn earworm larvae by the use of chromic oxide as an index compound. In gereral, the fall armyworm's ability to utilize diets with corn leaves was slightly better than the ability of the corn earworm. While the reverse was true with kernel diets, kernel diets were more highly utilized than silks by both species of insects.

Significant differences were found among 18 lines of corn (leaves, kernels, and silks) in the degree of stimulation to feed they furnished larvae of both fall armyworm and corn earworm. The plant parts that elicited a response as an arrestant in earworm larvae are listed in descending order, as follows: kernels, silks, dried seed, and leaves. In fall armyworm larvae the order was as follows: silks, kernels, leaves, and seed. Kernels with the highest amylose content gave the best feeding stimulant response for both corn earworm and fall armyworm.

In varietal evaluation tests conducted to locate new corn rootworm resistant germ plasm at Brookings, S. Dak., 44 synthetics, 4 Corn Belt inbreds (A297, OH05, OH45B, and 153RM) and 15 inbreds developed by the South Dakota State University, Plant Pathology Department for resistance to root rot also showed resistance to the western corn rootworm. One hundred superior performing inbreds in the breeding program have been advanced to the S-2 generation for further study and potential line development.

In studies conducted at Iowa State University under a grant on the biochemical basis for resistance of maize to attack by the European corn borer, a technique was developed using C^{14} to detect both DIMBOA and DIBOA, the chemicals believed to be associated with corn borer resistance in the corn plant. A technique was also developed using the isotope method for the estimating the amount of DIMBOA in corn.

Studies conducted under P.L. 480 project A7-ENT-25, India, which covers research of insect pests of maize, indicate that the stem borer, Chilo zonellus, reduces maize yield by 20%. It was also found that the percentage of infestation and damage was greatest in late sown crops. Several varieties were found to be more resistant to damage than others. The most resistant being A1 x Antiqua Gr.I and Cuba 11J.

2. Small Grain and Sorghum Insects. Years of cooperative research between Federal and State agencies in North Dakota culminated in the release of Fortuna, the first hard-red spring wheat variety ever developed that has both sawfly and rust resistant characteristics. Fortuna has out-yielded and been heavier in test weight than the sawfly resistant varieties Chinook and Rescue.

In Michigan the screening for resistance to the cereal leaf beetle in small grain varieties, breeder's lines, introductions, and segregating populations of crosses involving resistance was continued at two locations with approximately 8,000 entries in each nursery. Under the pressure of a high beetle infestation, approximately 55 varieties of winter wheat and a comparable number of spring wheats exhibited resistant reactions. The most common type of resistance observed in the wheats was non-preference of resistant varieties for oviposition. CI's 6671 and 6469 were the most resistant barleys to the cereal leaf beetle. The reactions in these lines involves the tolerance and non-preference types of resistance.

Approximately 500 wheat varieties selected for cereal leaf beetle resistance under field nursery conditions were tested for resistance in the laboratory, utilizing growth response, survival of first instar larvae, ovipositional preference, and egg production of mated females as measures of resistance. Eighteen spring wheat varieties were found with high levels of resistance to both the larval and adult forms of the beetle. Plant pubescence was coincidental with the highly resistant wheat varieties. Laboratory and field results on cereal leaf beetle resistance have been complementary in most instances. Winter wheat CI 8519 and the 18 spring wheat varieties rated as the top lines in the lab tests were the best lines in the field nursery.

In recent tests conducted at Stillwater, Okla., Dickinson Selection 28A wheat appears to have lost its resistance to the greenbug. Previously it was susceptible only to a biotype that occurred only under greenhouse culture conditions. During the past year DS 28A was susceptible to Stillwater greenhouse greenbug cultures and field-collected cultures from Wichita and Manhattan, Kans. There was no difference in rate of reproduc-on resistant DS 28A and susceptible Ponca wheats, whereas, the rate was reduced 45% on resistant Will barley as compared to susceptible Rogers barley. It is not known whether this loss of resistance is due to changes in the plant or in the greenbugs. Further tests are being made with greenbug cultures from Texas.

At Tifton, Ga., 36 sorghum lines were screened in the greenhouse for leaf damage by fall armyworm larvae. Line SA-392 (a Hegari type) exhibited the least damage (most resistance), while line FC-8962 (Kafir type) was the next most resistant.

Studies on physiological plant responses in relation to greenbug feeding on resistant barley plants were conducted at Brookings, S. D. Measurements were made of rate of photosynthesis, rate of respiration, chlorophyll content, fresh weight, dry weight, and area in relation to the amount of insect feeding. Comparisons of uninfested and infested leaves showed that chlorophyll content and rate of photosynthesis (based on fresh and dry weight and leaf area) decreased markedly in relation to increases in amount of insect feeding. Rate of respiration of infested leaves appeared slightly higher than uninfested leaves. Relationships between dry weight, fresh weight, and area of infested as compared with uninfested appeared to be unaltered during the course of this study.

Approximately 37 new crosses to introduce resistance to cereal leaf beetle into 6 commercial hard red spring wheats have been made at Brookings, S. D. A total of 580 F_3 lines from cereal leaf beetle resistant line x commercial spring wheat are available for testing in Michigan in spring of 1966. Four to five hundred lines from cereal leaf beetle resistant lines x commercial hard red winter wheats will be available for fall seeding.

Studies conducted under P.L. 480 project A7-ENT-31, in India, on investigations on the insect pests of sorghum and millets, show that the extent of loss due to shot fly, Atherigona indica, and stem borer, C. zonellus, was as high as 77.6% of grain. Two thousand and twenty-eight varieties of bajra were screened for resistance to insect pests. Some of these appear to be of good sources of insect resistant germ plasm for use in the breeding program.

H. Insect Vectors of Disease

1. Corn Insects. Dalbulus maidis, a vector of corn stunt virus, was collected in Texas on January 8, 1965, and in Louisiana in mid-July. This leafhopper had migrated eastward across Mississippi, where large field populations developed late in the season, and into Alabama by August 31, 1965. The leafhoppers were killed by below freezing temperatures in December. As of June 27, 1966, D. maidis has not been collected.

In tests conducted at State College, Miss., 3 native species of leafhoppers, Graminella nigrifrons, Deltocephalus flavicostus, and Exitianus exitosus, are being studied as possible vectors of corn stunt virus. All 3 are apparent vectors, producing virus-like symptoms in plants on which they are allowed to feed. D. maidis, a proven vector of corn stunt disease, completed several life cycles on gamagrass, Tripsacum dactyloides, a new host plant for this species.

In Mississippi, 669 entries composed of inbred lines, single and double crosses, commercial hybrids, and exotics, were tested for resistance to corn stunt virus. Different degrees of resistance were observed in native or locally adapted material indicating that unadapted resistant exotic material will not have to be used in breeding programs to develop resistant materials.

Field observations have indicated that the use of resistant hybrids by farmers in affected areas in 1965 has prevented the spread of corn stunt virus. A tabulation of commercial hybrids showing resistance to corn stunt virus was compiled for release to farmers.

In studies conducted under P.L. 480 project A10-ENT-5, Israel, on the hostplant-vector and hostplant-virus relationships in the rough dwarf virus disease of maize, it was discovered that D. striatella was the insect vector that carries and spreads the virus in the field. Subsequently, two more species of the same family were incriminated as vectors. These are D. pellucida and Sogatella vibix. The former species has a worldwide distribution and occurs also in North America, whereas the latter is apparently endemic in the Eastern Mediterranean, as it has hitherto been found only in Israel.

Studies were conducted at the University of Missouri under a grant on leafhopper vectors of corn viruses. A survey of insect vectors has been completed. Laboratory studies were conducted to develop techniques for rearing leafhoppers for transmission studies.

2. Small Grain Insects. A Delphacodes spp. collected at Brookings, S. Dak., late in the fall has been successfully colonized on rye. General biological studies including life history and host range investigations are being made of this insect. Such information would be of extreme value in the event that maize rough dwarf virus (MRDV) should be inadvertently introduced into the United States. American hybrid corns are known to be most susceptible in areas where MRDV occurs. This virus is only known to be transmitted in nature by species of Delphacodes.

Barley yellow dwarf virus has been successfully transmitted to and recovered from 5 varieties of sweet corn using the bird-cherry oat aphid, R. padi as the vector and a field isolate of BYDV collected at Davis, S. Dak. In all cases, the virus was recovered from test plants with non-infective aphids and serially transferred back to Black Hulless barley plants. Corn varieties were Aunt Mary, Golden Midget, Golden Sunshine, Golden Charlevoix, and Rainbow. This is the first report of transmission of BYDV to corn in the U. S. where infection was definitely established by serial recovery of the virus.

Rearing techniques for the leafhoppers, G. nigrifrons and D. sonorus have been worked out enabling the life histories to be studied in the greenhouse. G. nigrifrons completes its life cycle in an average of 34 days with approximately 13 days in the egg stage and about 4 to 6 days in each of the 5 nymphal instars. The host range study indicates that the majority of the cultivated small grains, corns, and sorghums are acceptable as both food and breeding hosts.

Field-collected aphids were pooled in groups of 25 aphids and screened for barley yellow dwarf disease throughout the autumn. A total of 35 pools of R. padi - R. rufiabdominalis, 8 pools of Forda olivacea, and 6 pools of M. avenae were screened. One pool of R. padi collected in late October transmitted BYD.

Barley yellow dwarf virus was recovered from migrating corn leaf aphids at Brookings, S. Dak. Major flights of corn leaf aphid, R. maidis, occurred during the first week of August. Five pools of 50 live aphids were formed from Johnson-Taylor trap catches and placed on healthy barley plants. Plants supporting two pools showed symptoms of barley yellow dwarf disease.

One hundred and fifty-two varieties of wheat were evaluated for barley yellow dwarf resistance in greenhouse tests in South Dakota. Ten wheat entries showed resistance to barley yellow dwarf. Fourteen of more than 1800 wheats in a field trial, showed good resistance to BYDV in field tests. These varieties have been incorporated into the winter and spring varieties breeding programs to develop commercial wheats with BYD resistance.

Twenty-nine hard red spring wheat varieties infested with BYVD in field plots at Brookings showed an average reduction in yield of 35.3%. Number of kernels per head and weight of kernels accounted for most of the reduction. The number of heads per foot of row appeared to be little affected by the virus in this trial.

Studies conducted under P.L. 480 project E8-ENT-1, Finland, indicates that Calligypona sordidula and C. obscurella were vectors of OSDV, oat streak dwarf virus, and WSMV, wheat streak mosaic virus, and Dicranotropis hamata the vector of OSDV. The injury caused to oats by C. sordidula was proved to be a virus disease. It was determined that the primary factor tending to increase the population of C. pellucida in its optimum area of occurrence is the constant cultivation of only cereals and hay. The most important factors reducing the population are natural enemies, winter mortality, and drought.

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AREA NO. 8. RICE INSECTS

Problem. Several species of insects including leafhoppers, the rice stink bug, rice water weevil, grape colaspis, stalk borers, and the sugarcane beetle damage rice in the rice-growing areas of the United States. Progress has been made toward the solution of some of the insect problems encountered in the production of rice but more effective, more economical, and safer insect control measures are needed. The appearance of resistance to certain insecticides in some rice insects stresses the need for basic information to overcome this problem. Additional emphasis should be given to new approaches to control rice insects and to evaluate rice varieties for resistance to major rice insects.

USDA AND COOPERATIVE PROGRAM

The Department's program on rice insects involves entomologists, agronomists, and plant breeders, and plant pathologists engaged in both basic studies and in the application of known principles to the solution of growers' problems. The research is being conducted at Baton Rouge, La., in cooperation with the Louisiana Experiment Station. Basic research on the control of damage by larvae of the rice water weevil, Lissorhoptrus oryzophilus, by increasing plant tolerance, is being conducted under a grant with the University of Arkansas, Fayetteville, Ark.; under PL 480, A7-ENT-5, India, a survey is being made of the natural enemies of pests of paddy.

The Federal scientific effort devoted to research in this area totals 1.2 scientists man-years. Of this number 0.3 is devoted to basic biology of the leafhoppers, rice stink bug, and rice water weevil; 0.3 to insecticidal control of rice stink bug and rice water weevil; 0.3 to varietal evaluation of rice for resistance to stink bug, rice water weevil, and vectors of rice diseases; 0.1 to insect vectors of hoja blanca; and 0.2 to program leadership. In addition Federal support for research in this area provides for 0.4 man-year in a research grant to the University of Arkansas for varietal evaluation of rice for resistance to the rice water weevil.

PROGRAM FOR THE STATE EXPERIMENT STATIONS

A total of 3.4 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Ecology and Nutrition

At Baton Rouge, La., a technique was developed for rearing the rice water weevil, Lissorhoptrus oryzophilus, in the greenhouse. This is the first time the weevil has been cultured under artificial conditions. Oviposition studies indicated that the rice water weevil deposited its eggs both below

and above the water line, predominantly in the first or second leaf sheath of the young rice plant. The maximum number of eggs per plant occurring 2 or 3 weeks after flooding. A field study on rice planted at weekly intervals over a period of 5 weeks, beginning April 20 showed that over 4 times the number of eggs were deposited in older seedlings (April 20 planting) than in the younger seedlings (May 18 planting) when egg counts were made 2 weeks after flooding.

Clumps of bullgrass, broom sedge, and smut grass collected in September 1965 at Crowley, La., averaged 4.7 diapausing rice water weevils per clump. There was no significant difference in the number of weevils on the 3 grass species.

Observations on overwinter larvae of Chilo plejadellus and Diatraea saccharalis in rice stubble, during 1965-66, showed that live D. saccharalis were rarely found in March and the overwintering populations of C. plejadellus were reduced about two-thirds. The tendency of D. saccharalis to overwinter at the bottom of the stalk where it is subjected to severe weather conditions probably accounts for high winter mortality in this species.

In studies conducted in India under PL 480 project A7-ENT-5, 36 species of insects were recorded as pests of paddy. Of these, 9 species of Lepidopterous borers were responsible for major losses to the paddy borer. Tryporyza incertulae was the most injurious and occurred throughout the rice-growing areas. The other borers in order of their importance were: Sesamia sp., Scirpophaga sp., Chilo partellus, Pseudaletia separata, Ancylolomia indica, Spodoptera cilium, Brachmia arotraea, and Leucania loreyi.

B. Insecticidal and Cultural Control

Nine experimental insecticides were evaluated for systemic action against Sogata orizicola. All materials except Niagara NIA-10242 exhibited some degree of phytotoxicity when used as seed treatments. Bay 39007 gave excellent control for 25 days following planting; however, both this material and Niagara NIA-10242 were incompatible with propanil, a commonly used herbicide in rice. Di-Syston, Isolan, and Phorate applied as a granular formulation in soil treatments at 2 pounds of toxicant per acre gave good control up to 33 days after treatment--No material was adequate at the one pound toxicant per acre rate.

Bidrin, carbaryl, phosphamidon, and Azodrin applied as a spray at the rate of one pound actual per acre gave good control. Solutions of 46 ppm of Bidrin, dimethoate, and Isolan, simulating the addition of insecticides to the flush water in a rice field, gave 50% control up to 15 days after treatment.

Granular formulations of Bay 25141 and Niagara NIA-10242 applied prior to flood at rates of 2 and 0.6 pounds per acre, respectively, gave adequate control of rice water weevil larvae. One application of as little as 0.3 pounds per acre of Niagara NIA-10242 also controlled the weevil. Niagara NIA-10242 and Temik showed sufficient systemic activity to cause significant reductions of the green rice leafhopper, Draeculacephala portola 6 days after flooding.

Investigations on the resistance of rice water weevil populations to aldrin revealed resistance occurring only on the Rice Experiment Station, Crowley, La., and at Jones and Alsatia in the northern part of Louisiana.

In germination tests, 5 insecticides had no effect on seed viability. All except AC 52160 and Bay 44646, lowered the viability of the seed, when seeded in water.

Seven insecticides and one combination of two insecticides were evaluated as seed treatments in the field against rice water weevil at both Crowley, La., and Stoneville, Miss. Aldrin at 0.25 pound (the recommended rates) and one pound per cwt. failed to control rice water weevil. The combination (aldrin-heptachlor) treatment was also unsatisfactory. Leafhoppers, D. portola, Graminella nigrafrons, and several other species were controlled with Niagara NIA-10242 seed treatments.

A technique for surveying for populations of the rice water weevil was also developed. Submersion of grass clumps containing weevils activated the diapausing adults which could then be readily recovered.

C. Biological Control

In studies conducted in India under PL 480 project A7-ENT-5, 33 species of parasites were recorded from paddy pests. Rhaconotus oryzae, Tropobracon schoenobii, Bracon chinensis, and Chelonus sp. were the commonest and fairly widely distributed parasites of the borers. Telenomus sp., R. oryzae, Goniozus sp., Glyptomorpha deesae, Isotima sp., and Hockeria sp. appeared to be new records on paddy borers in West Pakistan. Parasitism was higher on the larvae in stubbles than on those in the crop. Although a parasitism of up to 27.7% of the larvae of T. incertulas on 'Sathra' crop in May in Zone 3 and up to 41.1% of those in stubbles of 'Kangni' 27 in June in Zone 4 was recorded, the average parasitism on borers in all the ecological Zones as a whole was very low.

D. Varietal Evaluation for Insect Resistance

Seventy varieties or crosses representing either the commercial varieties in production or the more advanced potential varieties available from breeders of the southern rice belt were evaluated for resistance to both rice water weevil and borers. Marked differences between selections were apparent relative to rice water weevil larval infestation. Colusa and some

of the crosses with Rexora parentage received low infestation. Nova, Saturn, Zenith, Nato, Gulfrose, Century Patna 231, Fortuna, Bluebonnet 50, Toro, Arkrose, Lacrosse, Vegold, and the newly released variety, Dawn, had intermediate infestations. Early Prolific, Blue Rose, Supreme Blue Rose, Improved Blue Rose, and Calrose had heavy infestations. Crosses of PI215936 X C19214 from both the early and the midseason maturing long and long-slender grain rice variety types had low infestations. No significant differences were found in the resistance of these varieties/crosses to Chilo and Diatraea.

Preliminary results of field tests conducted under a grant by the University of Arkansas, indicated that higher nitrogen levels are associated with high rice water weevil larval infestations. Greenhouse tests indicated that the adult weevils prefer to feed upon the younger leaf blades which contain more sucrose and starch and less cellulose than older leaves. The weevils preferred older leaves for oviposition. The leaf-sheath was the preferred site of oviposition.

In India under PL 480 project A7-ENT-5, studies on 20 varieties of paddy including 8 fine and 12 coarse (16 native and 4 from the Philippines) have been carried out. Only one variety, 'Sonkari Kangni' (native), remained free from borer attack, while 'Daudzai' (native) had the highest average infestation during the season. Among the fine varieties 'Dokri Basmati' had the least borer attack, while 'Basmati' C621 and C622 had infestations of medium intensity. The other fine varieties were fairly heavily infested. On the whole late maturing varieties were more heavily attacked as compared with early ones.

E. Insect Vectors of Diseases

Progeny, of reciprocal matings of HBV transmitters to non-transmitters, were reared from the egg under aseptic conditions and constant temperature and photoperiod. Planthoppers that were progeny of non-transmitting females, transmitted HBV, although they had not fed on HBV diseased plant sources indicating masked virus infectivity. Adult planthoppers that acquired virus transovarially died sooner than others.

Two thousand and ninety-seven males and 863 females, active vectors of hoja blanca virus, were reared for use in cooperative tests with Crops Research Division to develop varieties resistant to this disease.

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AREA NO. 9 COTTON INSECTS

Problem. The control of insects is a major cost factor in the production of the cotton crop. Although current insecticide control measures for cotton pests have been effective enough to keep growers in the cotton production business, improvements are needed in safety of their use, in their efficiency, and in the reduction of undesirable residues. Twenty species of cotton pests have developed resistance to certain insecticides emphasizing the need for developing basic information to solve or avoid the problem and to develop other methods of control that are more effective, economical or desirable. More research on approaches to control such as sterile male or female techniques, repellents, sex and other attractants, biological control agents such as pathogens, and safer insecticides and more effective ways of appyling them is needed to develop improved methods of control. Methods of eliminating the pink bollworm and boll weevil from newly infested areas and possibly eradicating them from all areas are needed. The successful synthesis of the pink bollworm sex attractant should be exploited fully to determine its potential in the detection and control of this pest. The pink bollworm was found in limited areas in California for the first time in 1965. In recent years the boll weevil extended its range to west Texas and poses a threat to cotton in New Mexico. A boll weevil found attacking cotton in northwestern Mexico and Arizona poses a threat to cotton production in New Mexico and California. It was found in California for the first time in 1965. More knowledge is needed on the biotic potential of various pests and on factors which influence it. This information could serve as a basis for advising growers when control measures for the various pests will or will not be required, and determining the time when the initiation of eradication or control programs would give such programs the greatest chance of being successful.

USDA COOPERATIVE PROGRAM

Research on cotton insects is conducted at field laboratories located at Florence, S. C.; State College, Miss. with satellites at Stoneville, Miss. and Tallulah, La.; College Station, Tex.; Brownsville, Tex. with a satellite at Waco; Tucson and Phoenix, Arizona and; Baton Rouge, La.

Various aspects of research being conducted are as follows: (1) studies on the biology, ecology, physiology, and nutrition of such insects as the boll weevil, bollworm, tobacco budworm, pink bollworm, cabbage looper, beet armyworm, lygus bugs and salt-marsh caterpillar; (2) studies to determine the mode of action and fate of various chemicals in and on such insects as the bollworms and boll weevil to determine the mechanisms by which the insects are able to develop resistance to insecticides; (3) studies to discover and develop more effective conventional and systemic insecticides and to improve methods of applying them to increase their efficiency in controlling various cotton pests; (4) studies to discover pathogens or

other biological control agents and to develop methods for using them to control the boll weevil, bollworm, tobacco budworm, cabbage looper, and other cotton pests; (5) studies to discover and develop cotton varieties resistant to or tolerant of attacks of such pests as the bollworm, tobacco budworm, cabbage looper, pink bollworm, boll weevil, cotton aphid, and spider mites; (6) studies to develop the sterile-insect technique and procedures for using it alone or in combination with other methods for controlling or eradicating the boll weevil and pink bollworm; (7) studies to develop practical methods of employing biological active compounds such as the attractant, feeding stimulant and repellent of the cotton plant for the boll weevil, and sex attractants for controlling cotton insects; and (8) development or improvement of equipment for insect control such as stalk shredders, machines to collect and destroy boll weevil infested cotton squares, gin and oil mill machinery, light traps, ultrasonic, and electronic machines.

The research is conducted in cooperation with the Agricultural Experiment Stations of South Carolina, Mississippi, Louisiana, Texas, and Arizona, and with the Plant Pest Control, Crops Research, Soil and Water Conservation, and Agricultural Engineering Research Divisions, ARS, USDA. Research is also supported by grants, contracts, or cooperative agreements with Texas, Mississippi, California, Arkansas and Alabama Agricultural Experiment Stations, and the Southern Research Institute.

The Federal Scientific effort devoted to cotton insects research totals 54 professional man years. Of this number 19 are devoted to basic biology, physiology, and nutrition; 14 to insecticidal and cultural control; 6.0 to biological control; 5.5 to insect sterility, attractants and other new approaches to control; 1.5 to evaluation of equipment for detection and control; 4.5 to varietal evaluation for insect resistance; 0.5 to insecticide residue determinations; and 3 to program leadership.

In addition Federal support for 2.1 man-years of research in this area is provided in contracts and grants. Of this total 0.9 is devoted to basic biology, physiology and nutrition; 0.9 to biological control; and 0.3 to insect sterility, attractants, and other new approaches to control.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 32.5 professional man-years is devoted to this area of research.

PROGRESS--USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Boll Weevils. In 1965 spring woods-trash examinations for hibernating boll weevils were made in central Texas, northeast Louisiana, Delta and Hill sections of Mississippi and in four areas in the Carolinas. Comparative survival since 1961 in the various areas was as follows:

Area	Weevils Per Acre				
	1962	1963	1964	1965	1966
Central Texas	1361	452	97	4925	1098
Northeast Louisiana	2233	121	1049	3052	247
Mississippi	1132	13	289	995	1425
South Central South Carolina	1667	914	753	1855	484
Coastal Plains, North & South Carolina	3654	1560	2742	10164	3307
Piedmont North and South Carolina	2833	350	134	--	3469
North Central North Carolina	968	161	107	1371	1425

In northeast Louisiana survival was lower than in any recent year except 1963. In Madison Parish, La. the numbers surviving were lower than in any year since 1948. The survival percentage was 16% compared with an average of 42% for the 30 year period, 1935-1965. Numbers surviving in Mississippi were higher than in any year since 1960. The number of weevils surviving in Florence, S. C. was 4035 per acre but is about 73 percent less than the number that survived last year.

Studies of the Boll Weevil Research Laboratory at State College, Miss. showed that boll weevil migration began 3 to 6 weeks earlier in Oktibbeha County in 1965 than in 1964. This corresponded with much higher populations in 1965. Most migrating weevils were of the reproducing type and 63% of those collected were females.

Weevil activity was very light in hibernation cages in January, February and March at Waco, Tex. There was no weevil activity in cages in which field collected weevils were installed on November 1, 1965, in cages in which green bolls collected in November were installed, or in cages containing weevils removed from ground trash in December and March. Two weevils were active on March 21 and one on March 29 in cages containing bolls collected from standing stalks in March.

Volunteer and stub cotton reduced the effectiveness of the cultural control program against boll weevils in the winter of 1965 and 1966 in the lower Rio Grande Valley of Texas. Reproducing boll weevils were collected from regrowth cotton through the winter. An estimated 10,923 boll weevils per acre emerged from squares collected from a 20-acre field in January.

Trash and boll surveys in mid-March in the Presidio, Tex. - Ojinaga, Chihuahua area showed that very small populations of boll weevils remained in hibernation in ground trash and none were found in bolls after

the fall diapause control program of 1965. Four male and 2 female weevils emerged from 8045 caged infested bolls. The last emergence occurred between March 24 and April 12.

In studies by the Tucson, Ariz. laboratory, major infestations of the boll weevil complex continued to be associated with stub cotton culture during 1965. Several damaging infestations were present in planted cotton in southern Ariz. by late July and the boll weevil was present throughout the cotton growing region with the exception of the extreme western area during the fall of 1965.

Boll weevil complex adults survived the winter in bolls on the soil surface and in those buried 3 inches in Yuma County, Ariz. Irrigation of bolls on the soil surface did not enhance weevil survival. Weevils released from bolls readily survived in leafy trash. Adults were taken from trash beneath desert vegetation near cotton fields and at nearly every location where the trash was collected and inspected between January 19 and March 4, 1966.

In studies at Tucson, Ariz. exposure to temperatures of 110,to 125° F for several days was necessary for kill of boll weevil complex larvae in squares on the ground. When infested cotton squares were exposed to temperatures of 80, 95, 110 and 125° F for 24 hours the percentages producing adults were 47.5, 37.5, 25.0, and 3, respectively.

In studies at Waco, Tex. the average longevity of 48 boll weevil females that emerged on May 12 lived 30 days. Maximum longevity for any one individual in 1961, 1960, 1958 and 1957 was 99, 51, 63 and 44 days, respectively.

The seasonal history of the boll weevil in the Texas High and Rolling Plains with special emphasis on its fall biology was studied under a cooperative agreement with the Texas Agricultural Experiment Station, Texas A&M University. In the spring of 1965 the number of boll weevils that survived the 1964 control program to infest seedling cotton averaged 20 adults per acre. Numbers remained stable through July until mid-August but increased tremendously in late August with populations on August 27 estimated at 13 times that on July 23. Onset of diapause in field populations was low until early September. Ground trash examinations indicated an 89% reduction in overwintering boll weevil populations in the known heavily infested areas of Dickens and surrounding counties in the spring of 1965. Unseasonably warm temperature hastened weevil emergence with first emergence occurring on March 22, 1966. This compared with first emergence on April 1, 1965 and March 28, 1964. Shinnery oak leaf litter seemed to be the most important overwintering site for the boll weevil in Dickens and surrounding counties.

In studies at Tucson, Ariz. boll weevil complex adults fed on Sphaeralcea spp. after emerging from hibernation but failed to reproduce on it in the insectary. The data indicates that Sphaeralcea spp. may be a food plant utilized until cotton becomes available.

In preliminary studies of the flight of laboratory-reared boll weevils in flight mills at Fort Detrick, Md., females averaged 1.43 miles and males 1.32 miles in initial sustained flights. In exhaustive flights females averaged 2.21 miles and males 2.06 miles. The longest exhaustive flight was almost 11 miles. Speed of flight on the mills ranges between 2.05 to 2.42 miles per hour. Flight activity was appreciably greater at 85° than at 80 or 90° F.

In studies by the Boll Weevil Research Laboratory, boll weevils flew 10 miles within 48 hours from a release point to potted cotton plants. In 1965, releases were made in Kansas at points 5, 10, 15, 30 and 40 miles from potted cotton plants. An average of approximately 225,000 marked weevils were released at each point except only 120,000 at 5 miles. Two weevils from the 5-mile point and two from the 10-mile point were recovered. None were recovered 15, 30, or 40 miles from the release point.

Weevils flew infrequently in wind exceeding 5 mph. Usually weevils face into the wind when preparing to fly or when taking flight, but they apparently fly at random with respect to wind direction, except where a mating stimulus is involved.

Studies at the Boll Weevil Research Laboratory indicated that metabolism of uric acid to amino acids is not universal among insects. This conversion does not occur in house fly pupae or German cockroach nymphs. A number of other insects need to be studied before it can be said this phenomenon is unique to the boll weevil.

Gas chromatographic analysis at Baton Rouge, La. show that cotton squares contain varying amounts of -sitosterol, campesterol and stigmasterol. Analysis of adults reared from diets containing each of these sterols showed that the weevils were able to convert them all to cholesterol. Based on the amounts of un-metabolized dietary sterols remaining in the newly-emerged adults, it was concluded that the immature stages of the weevil converted the three sterols to cholesterol in the following descending order: stigmasterol, -sitosterol and campesterol. More stigmasterol appeared in the larval excreta indicating less efficient absorption of this sterol from the diet than with the other sterols.

Analysis with thin-layer chromatography showed that two week-old adult boll weevils contained 6 main steriods. These sterol metabolites were detected on chromatograms by means of radio-autography when analyzing C^{14}-labeled extracts or by spraying with color-producing reagents such as antimony trichloride. The patterns for the males and females were the same. Feces of adults contained 4 principal steriods with R_f values different from those of the steriods extracted from the weevils. The weevils as well as the feces contained a number of minor steroids as well.

Weevils synthesized trehalose and glycogen from both xylose and glycerol. Although crude lipid levels were about the same in xylose and glycerol fed

weevils, trehalose and glycogen levels were about twice as high in the glycerol than in the xylose fed insects. Glycerol feeding led to trehalose and glycogen concentrations that were similar to those of sugar fed weevils; however, crude lipid levels were about two times higher in the weevils fed sugar than in weevils fed glycerol. About 35% of the trehalose of late last instar larvae of the boll weevil and about 28% of the glycogen of adults fed 20% sucrose for 10 days was found in the gut.

The trehalose content of various developmental stages of boll weevils was determined as follows: late last instar larva 204 µg, a prepupa 180 µg, a 0-24 hr. old pupa 182 µg, a 78-108 hr. old pupa 158 µg, 0-2 hr. old adult 158 µg, and 16-24 hr. adult about 135 µg of trehalose. The data indicated that the greatest decline in trehalose titer comes after adult eclosion.

Boll weevils could not maintain high rate of egg production on a diet containing cholestanol as the only sterol. However, egg hatch remained high even while egg production was declining. By contrast, eggs from weevils fed a diet containing inadequate amounts of cholesterol and no cholestanol failed to hatch. Quantitative gas chromatographic analyses of sterols from eggs and adults showed that the improved hatch resulting from the addition of cholestanol to the diet was not due to an increased carry-over of cholesterol from the immature stages. The small amounts of cholesterol in eggs from cholestanol-fed parents was effectively "spared" or supplemented by the relatively large amounts of cholestanol that were also present. This enabled the embryo to survive. Sparing of cholesterol in the adult was less efficient, and as a result, egg production soon declined.

Newly synthesized fatty acids were rapidly incorporated into phospholipids in the boll weevil, or were esterified with glycerol or sterol. The feeding history and developmental stage of the adult determined the final location of the newly synthesized acids. Unfed newly emerged adults incorporated fatty acids mainly into the phospholipids, whereas 6-day-old fed adults incorporated fatty acids into the glyceride fractions.

There was no synthesis of sterol from injected acetate in the adult boll weevil. Purification by digitonin precipitation followed by thorough washing of the sterol digitonide showed that sterol fraction was not radioactive. All the associated radioactivity was left in the supernatant liquid fraction. Thin-layer chromoatography of the original extract showed that it had been contributed by diglycerides contaminating the sterol fraction.

Methylation, hydrolysis, and silanization of boll weevil glycogens gave an additional peak in gas chromatography analysis over that obtained by the same treatment of a mammalian glycogen. When chromatographed, boll weevil glycogens contain an additional material of retention time intermediate between α and γ-tetramethylglucopyrandside.

The highest specific activity in lipids synthesized from differentially labeled glucoses occurred in those labeled positions giving the lowest $C^{14}O_2$

production. Data with glucose 3, 4-C^{14} and labeled pyruvate indicate that pyruvate is a principal intermediate and is converted to acetate. However, an alternate pathway for the incorporation of pyruvate into lipid appears to be present in the boll weevil, suggesting direct entry of pyruvate into the Krebs cycle, and the possible involvement of the glyoxalate cycle in fatty acid synthesis.

Glucose, sucrose, fructose and their related glycolytic end-products, pyruvate and acetate, were readily converted into long chain fatty acids and hydrocarbons by larval and adult boll weevils. Comparison of the radiorespirometric formation of $C^{14}O_2$ from adults infected with differentially labeled glucose and pyruvate with the specific activity of lipid synthesized from these two substrates showed that glycolysis is the principal pathway for glucose catabolism. The complete patterns now reveal that the weevil also possesses a very active pentose phosphate cycle which accounts for a considerable oxidation of glucose. Recombinations of labeled carbon atoms within and between intermediates of the pentose cycle allow for synthesis of labeled fatty acid from those carbons of glucose which could not ordinarly enter fat synthesis by glycolysis alone.

Glycogen was depleted much more rapidly than lipid in diapausing boll weevils. Glycogen content decreased 40%. Adults resumed full reproductive activity and glycogen and lipid levels increased significantly when adults were again exposed to higher temperature and food. Gas-liquid chromatography of both total and triglyceride fatty acids was high (1.60 to 1.90) during diapause, and returned to the lower values (0.76 to 1.4) characteristic of reproducing weevils when feeding and egg laying was resumed.

Topical applications of the juvenile hormone-mimicking substance, 10, 11-epoxyfarnesenic acid methyl ester had little effect on the boll weevil. Treatment may have partially inhibited diapause, but did not affect fecundity. Applications of up to 5 ug of material to young pupae failed to produce adults with pupal characteristics.

Diapause was terminated in field-collected weevils by exposing them to 13 hour periods of ultra-violet irradiation in the laboratory. Longer wavelengths were not quite as effective. Weevils held in continuous darkness emerged from diapause almost as soon as some of the weevils exposed to visible light, indicating that other factors also contributed to diapause termination.

When weevils were irradiated with infra-red from a sniperscope lamp for periods of 11 and 13 hours each day, an average of 34 percent attained diapause in the 11-hour group and 39 percent in the 13- hour group. An average of fifty-three percent of control groups wxposed to 11 hours of white light attained diapause. Diapause was induced by exposing eggs to short light periods. Subsequent stages of the weevil were exposed to infra-red radiation in order to stimulate the larvae in penetrating the diet. The average percentage of the weevils in diapause after being exposed to an 11 hour light

period during the egg stage only was 64 percent. The percentage of control groups in diapause after exposure to an 11 hour daily period of flourescent light at all life stages was 60 percent while that of control groups with 13 hours of light exposure daily was 30 percent.

Studies indicate that boll weevils lose their ability to diapause after being maintained for many generations in the laboratory. Only 33 percent of the weevils from one strain (Castelberry) entered diapause when exposed to an 11 hour daily light period. These weevils had been maintained in the laboratory for over 30 generations.

First-generation boll weevils from overwintered parents diapaused in studies at Baton Rouge. The boll weevil differs in this respect from the bollworm.. It has been reported that very few first generation bollworms diapause even under conditions of short daylength and low temperature. Mating had little effect on induction of diapause in the boll weevil. The percentage of diapause in mated males was slightly higher than for unmated males, but there was no difference between mated and unmated females.

As in other insects, the fatty acid content of the female boll weevil's diet influenced the fatty acid spectrum of the eggs. However, this is not easily observed in insects feeding on low fat diets when the egg lipid spectrum resembles the fatty acids that the female can synthesize from other constituents.

In studies at the Boll Weevil Research Laboratory the incorporation of deuterium oxide (heavy water) into boll weevil larval diets caused a decrease in reproductive potential of adults. Levels of D_2O in the diet above 35% caused significant declines in larval developmental rate, pupal weight, and percentage of adults produced.

At College Station, Tex. it was determined that the wheat germ diet can be used for rearing boll weevil adults and larvae. Added cholesterol was necessary in the larval diet for maximum adult yield.

Over 2 million marked boll weevils were produced during the third quarter, 1965 in the Boll Weevil Research Laboratory. The estimated cost of production, excluding laboratory space or inventory items was $2.75 per 1000.

Sperm production in the boll weevil continued until shortly before death in laboratory tests at Florence, S. C. Two males over 90 days old produced sperm and mated effectively within 3 days of their death.

Parthenogenetic reproduction was noted at Florence. When a black, unmated boll weevil female produced 55 eggs (31 in and 24 on squares) from which 14 adults developed on egg white diet, two of the F_1 but none of the F_2 generation were parthenogenetic. Black females from this culture are being held to determine if parthenogenetic reproduction reoccurs.

Metabolism of α and β isomers of phosphamidon were studied in the cotton plant at College Station, Tex. Studies of the fate of the nontoxic α isomer and the toxic β isomer of phosphamidon in cotton plants indicated that the β isomer was slightly more stable. Also, the α isomer is more readily lost from the surface of cotton leaves following foliar application. Both isomers were quite stable under acidic and mild alkaline conditions. Under strong alkaline conditions, however, the β isomer was less stable than the α isomer. Age of plant affected uptake of phosphamidon applied to stems. Results of studies with C^{14}-labeled B-phosphamidon in lanolin showed that: (1) an increase in area of the cotton stem treated increased the uptake of phosphamidon by the plant; (2) young cotton plants with green waxy stems took up more C^{14} phosphamidon than older plants with "barked" stems; and (3) cotton plants given two phosphamidon stem treatments (only the second treatment was C^{14}-phosphamidon) took up much more C^{14}-phosphamidon than plants treated once.

The toxicology of Geigy 13005 was studied with C^{14} and P^{32} labeled material at College Station, Tex. Results indicated that this compound decomposes quite slowly within cotton plants but is rapidly lost from the leaf surface. One unidentified metabolite (Unknown A) is completely water soluble and is a potent cholinesterase inhibitor.

Preliminary data from replicated laboratory tests at Florence, S. C. indicated that differences in fatty acid composition between toxaphene treated boll weevils is not a normal variation in the population but is due to a metabolic change induced by the insecticide.

2. Bollworms. Dissection of Heliothis moths collected in light traps at Stoneville, Miss. during the season indicated that the moths were in all stages of sexual development. By far the greater portion of the females had mated.

Important early season hosts of the Heliothis complex in the Stoneville area are crimson clover and wild geranium. Several larvae of both H. zea and H. virescens were collected with sweep nets on these hosts in May. Alfalfa, also, is an important host of H. zea in that month.

Initial infestation of one first instar Heliothis zea larva per cotton plant on July 16 under caged conditions resulted in almost 50% of the bolls being injured by September 10. When plants in large screen cages were infested at the rates of 4, 3, 2, and 1 larvae per 4 plants on July 16, the injured boll counts on September 10 were 48.5, 41.8, 31,8 and 27.0% respectively. The yield was reduced 9% in the highest treatment level over that of the check.

Eggs and larvae collected in Delta cotton fields indicated that Heliothis virescens was the predominant species in June and late August. Although numbers collected were limited, a large number of eggs collected on cotton in June and early July were those of the granulate cutworm. At Tallulah, La. 43% of the larvae hatched from eggs collected from cotton terminals from

July 12 to 22 were H. zea, 20% H. virescens, and 38% Feltea subterranea. A high percentage of larvae collected from cotton from July 22 to September 3 were H. zea.

At Waco, Tex. no H. virescens larvae were collected on host plants during April, May and June 1966. All 265 larvae collected from 9 different early-season host plants were H. zea. However, seventy-four percent of larvae collected on cotton during June were H. virescens although only one tobacco budworm moth was collected through June in the light trap.

In studies at Brownsville, Tex. the number of Heliothis eggs and larvae was estimated on 4800 acres of Nicotiana repanda during March and April, 1966. Eggs of H. zea (17,456) and of H. virescens (41,785) were most abundant from March 30 to April 11. Larvae were most abundant in the last sample taken from April 18 to 25 but numbers were small when the number of eggs were considered.

At College Station, Tex. analysis of various stages of the bollworm reared on different diets indicated no synthesis of either linoleic or linolenic acid. There was no apparent interconversion of these acids.

At Stoneville, Miss. Heliothis spp. larvae completed development on presquaring cotton plants, but moths from them failed to live long enough to oviposit. The larval survival rate on very young cotton plants was low but a number of larvae did complete development and they pupated. Several moths emerged but all of them died within 3 days after emerging from the soil.

In studies at Baton Rouge, La. major classes of phospholipids of Heliothis zea pupae have been separated and tentatively identified. The major component is a cephalin probably phosphatidyl ethanolamine. Large amounts of phosphatidyl choline also are present. Traces of other phosphatides also are detectable by thin layer chromatography and have a chromatographic behavior similar to sphingomyelin, cerebroside and phosphatidyl inositol.

3. Pink Bollworm. More pink bollworm moths were collected in a light trap at Waco, Tex. in 1965 than in any previous year except 1958. Pink bollworm moths collected in a light trap increased each year from 1953 to 1958 with the highest collections being made in 1958. Collections decreased sharply in 1959 with little difference in numbers collected during the years 1959-1962. Fewer moths were collected in 1963 than in any year since 1954. There was a sharp increase in 1964 when more moths were collected than in any year except 1958. There was a further increase in 1965 when the number collected was 2.3 times that of 1964.

Volunteer and stub cotton reduced the effectiveness of the cultural control program against pink bollworms in the winter of 1965 and 1966, in the Lower Rio Grande Valley of Texas. An estimated 1,873 pink bollworms per acre emerged from squares collected from a 20-acre field in January, 1966.

At Waco, Tex. 129 and 143 pink bollworm moths, respectively, emerged between May 11 and June 29, 1966 from two 18-gallon collections of green bolls installed in November, 1965 on the soil surface and on screen wire 6 inches above the ground in hibernation cages. Twenty-four pink bollworm moths emerged from hibernation cages containing 100 pounds of bolls collected from standing stalks in 3 fields in early March 1966.

A pink bollworm survey was made April 13 to 21, 1966 to determine location of hosts, to estimate populations, and to start a sex lure trapping program on St. Croix, U. S. Virgin Islands. Patches of wild cotton were found scattered about the central and southwestern parts of the island and boll examinations showed an average of 0.33 diapause larva per open boll. Thespesia malvaceous plants were common thoroughout the island in open areas. It was estimated that the diapause population did not exceed 50,000. Adult males were taken in sex lure traps in localities where wild cotton, Thespesia, Hibiscus, and herbaceous Malvaceae were growing.

4. Other Insects. In a study at Stoneville, Miss. one adult tarnished plant bug per plant per week for 5 weeks was released in large field cages. Plant bug infestations just before or during early fruiting reduced first picking by almost 50% compared with uninfested cotton, a reduction of 1/4 to 1/3 bale per acre.

Lygus hesperus is the predominant species of lygus bugs in Arizona except in eastern portion of state where L. linolaris is more abundant. Sweep net counts made in alfalfa at 2-week intervals beginning April 20 through September 24 resulted in a total count in western Arizona, Yuma to Phoenix, of 8885, or 87% L. hesperus and 453, or 4%, L. lineolaris. In eastern Arizona, St. David to Safford, similar counts resulted in a total of 1789, or 69%, L. hesperus, and 500, or 20%, L. lineolaris.

Tarnished plant bug females oviposited viable eggs after being removed from hibernation quarters at Stoneville, Miss. Each plant bug was kept in an individual container from the time she was removed from ground trash until she died.

Hardwick adult moth food improved oviposition of salt-marsh caterpillar adults in studies at Tucson, Ariz. Female moths fed Hardwick moth food produced more fertile eggs than unfed moths, than those fed distilled water, or than those fed 5% sugar solution. The several adult diets had no effect on the longevity of the female adults. Life cycle of Eucelatoria armigera (Coquillett), a common tachinid parasitic on Heliothis zea and H. virescens was studied at Tucson, Arizona. The developmental period varied from 39.7 days at 59° to 11.5 days at 90° F.

At College Station, Tex. the use of cotton plants labeled with P^{32} demonstrated that Geocoris sp. and Nabis sp. feed on cotton plants. Feeding on the plant was reduced very little when Heliothis eggs were on the plants.

More than a 5-fold increase in the colony of 73 Bracon kirkpatricki adults received from Kenya was obtained in the first generation by exposing cotton squares artificially infested with boll weevil larvae to the parasite, at the Boll Weevil Research Laboratory.

Three generations of L. lineolaris and two of L. hesperus were reared on artificial diets in the laboratory at College Station, Tex. A liquid diet with a water extract of alfalfa meal was the most satisfactory of diets tested.

Salt-marsh caterpillars require linolenic acid in the diet. Also, the addition of α-tocopherol to the diet increased survival. A satisfactory diet and rearing method have been devised and five generations of the insect have been reared.

B. Insecticidal and Cultural Control

1. Boll Weevil. In field tests at Waco, Tex. Matacil, NIA-10242, Azodrin, and MC-A-600 were as effective against a moderate boll weevil infestation as carbaryl. All treatments reduced the infestation significantly below that of an untreated check and there was no difference among treatments. In another experiment the same materials were effective against a heavy boll weevil infestation.

In field cage tests at Florence, S. C. several candidate insecticides were effective against boll weevils. Laboratory reared weevils were slightly more tolerant of the insecticides and environmental conditions of the test.

In a preliminary large-field non-replicated plot test at Florence, S. C. comparing methyl parathion at 1.0 lb/acre with and without black strap molasses in 2 to 5 gal. of spray/acre, better weevil control was obtained with the addition of the molasses. However, this combination was not better than azinphosmethyl + azinphosethyl + DDT.

In a replicated large-plot field test at Florence, Azodrin at 0.6 lb/acre, MC-A-600 at 1.0 lb/acre and Matacil at 2.0 lb/acre were as effective against the boll weevil as the azinphosmethyl + azinphosethyl + DDT (0.18 lb. + 0.18 lb. + 1.0 lb. per acre) standard.

Five applications of technical malathion applied as an ultra low volume spray at 5-day intervals plus 3 applications at 10-day intervals reduced boll weevil populations in the Presidio area in the fall of 1965. The applications which commenced September 6 greatly limited the number of weevils entering diapause and appears promising for eradication.

In a replicated experiment conducted in isolated cotton fields in Carroll County, Mississippi comparing three rates of azinphosmethyl (.25, .19, and .125 lb/acre) applied as ultra-low-volume sprays with the conventional methyl parathion water emulsion standard (0.5 lb/acre in 4 gals. water, only the

lowest rate of azinphosemthyl was less effective than the standard. Extensive woods trash examinations in the fall of 1965 indicated that the reproduction-diapause control treatments gave a 94% population reduction when compared with the untreated check. Examination of woods trash in the spring of 1966 indicated a 98% reduction.

A light boll weevil infestation developed late in June, 1965 in an experiment conducted at Waco to compare systemic insecticides for early-season insect control. There were significantly fewer boll weevil punctured squares in plots that received Temik at 1.3 pound per acre in the furrow at planting plus 1.8 pound as a side-dress application at squaring than in plots receiving 2.0, 1.3, and 0.6 pound per acre of Temik, 1.1 pound of NIA-10242, or 1.1 pound of phorate only in the furrow at planting. However, early in July there was a significantly heavier bollworm infestation in the former treatment than in all other systemic treatments and untreated check.

Side-dress applications of Temik granules gave good control of boll weevils 4 days after application in a cage test at Stoneville, Miss. One pound per acre side-dressed on each side of the row of cotton was more effective than 2 pounds on one side. Accurate data on the period of effectiveness is not available but it appeared to be completely ineffective 3 weeks after application.

At Waco, Texas kill of laboratory reared boll weevils caged on cotton plants side-dressed with Temik was good 6 days after application but decreased sharply at 13 and 20 days. In field experiments a granular formulation of Temik applied as a side-dress at 1.0, 2.0 and 3.7 lb/acre gave overwintered boll weevil control equal to that obtained with 2 foliar applications of azinphosmethyl at 0.25 lb/acre. Each treatment reduced the infestation significantly below the check with no difference among treatments.

Results of greenhouse bioassay tests at College Station, Texas in which cotton plants were side-dressed with single or multiple applications (all plants receiving the same total amount of toxicant) of Temik showed that the multiple applications prolonged the length of effectiveness.

Results of studies of systemic activity of Temik-S^{35} showed that this toxicant is taken up readily by cotton plants when applied to the stem or soil. Significant quantities of Temik-sulfoxide were recovered in cotton squares from plants grown in soil treated with Temik.

At Tallulah, La. mortality of boll weevils caged on cotton plants that had been treated with a granular formulation of Temik at 1 pound per acre in the furrow at planting and side dressed with the same formulation and dosage when the plants were in the pin head square stage was 86%.

In replicated small-cage field tests at Florence, South Carolina, Temik at 1.0 lb/acre applied in-furrow at planting gave more than 90% boll weevil mortality until plants began to square. In replicated small plot field tests,

side-dress applications of Temik at 5.0, 6.5, 8.0 and 13.0 lbs/acre was as effective as carbaryl at 2.0 lbs/acre applied conventionally until boll weevil migration. Additional material applied 3 weeks after the original application did not appear to appreciably enhance the effectiveness of the original application. The material was ineffective against the bollworm and had no adverse effect on fruiting, yield, germination of seed, lint percentage or seed index.

Preliminary studies indicate that Temik exists for a very short time in cotton plants as it is rapidly converted to Temik-sulfoxide. Temik-sulfoxide is quite stable in the plant and apparently is the compound responsible for extended insecticidal activity. Temik is readily taken up by cotton plants for only about a week when applied as a soil treatment in the greenhouse. It is readily converted to its sulfoxide in the soil. Temik-sulfoxide is a more potent cholinesterase inhibitor than Temik, but is less toxic to boll weevils in topical applications. Temik is readily converted to its sulfoxide in insects. This conversion is slowed down considerably by the synergist, sesamex. These studies were conducted in direct cooperation with the Texas Agricultural Experiment Station.

Results of preliminary greenhouse tests indicated that a slow release Temik formulation for soil treatment was more effective against boll weevils than the formulation currently available. In experiments, four weekly applications of Temik to potted cotton plants were more effective than a single treatment equal to the total toxicant of the four weekly treatments.

2. Bollworms. At Waco low volume aerial applications of technical malathion at the average rates of 0.9, 1. and 1.3 pounds and Methyl Trithion at 0.8 pound per acre gave no control of bollworms. After 3 applications plants were almost completely stripped of fruit. In another experiment low volume applications of malathion and malathion plus Abate at 25 ounces per acre gave no control of bollworms. Good control of a heavy bollworm infestation was obtained with 2.0 pounds of toxaphene plus 1.0 pound of DDT plus 0.5 pound of methyl parathion in a low volume application. This mixture gave significantly better control than the same mixture applied as an emulsifiable concentrate, and than 1.0 pound of malathion plus 1.1 pound of TDE, and 1.3 pound of malathion plus 0.5 pound of endosulfan applied as low volume sprays. At Tempe, Ariz. 5 and 8 ounces of naled and 8 and 16 fluid ounces of malathion applied by aircraft failed to control bollworms. TDE at 2 quarts (3 pounds) per acre applied by plane at a height of 20 feet failed to give control. When applied 5 feet above the cotton the population was reduced but phytotoxicity was severe. A mixture of malathion at 1 pound plus TDE at 1 pound (1 quart) per acre failed to give bollworm control.

In tests at Florence, South Carolina with technical materials, solutions, and suspensions applied with a low volume mist sprayer, malathion plus TDE gave the best control of bollworms.

In field experiments in Central Texas where good control of a heavy bollworm infestation was obtained with low-volume applications of technical insecticides, increases in yield over an untreated check ranged from 911 pounds seed cotton per acre in plots treated with malathion plus endosulfan to 1185 pounds in plots treated with toxaphene plus DDT plus methyl parathion.

At Brownsville, laboratory tests indicated that alternating applications of effective bollworm toxicants with different modes of action were more effective than applications of a single toxicant. An application of methyl parathion spray followed by an application of Matacil and then by an application of toxaphene plus DDT or an application of toxaphene plus DDT followed by an application of Matacil spray gave superior control to applications of methyl parathion.

In laboratory tests at Brownsville, 2-day-old residues of two new formulations of naled applied as waterless sprays gave 45% mortality of tobacco budworm larvae compared with no mortality from 2-day-old residues of the emulsion sprays.

In studies at Brownsville, Tex. plowing of a pepper field containing overwintering H. zea pupae effected a 55% reduction in spring-emerging moths compared with an unplowed area. An average of 0.53 moths per square yard emerged from the unplowed area with the peak occurring Apr. 1-15. Plowing of a late-planted cotton field in January caused 100% mortality of H. zea and H. virescens overwintering pupae. An average of 0.32 and 0.97 moths per square yard of the respective species emerged from the unplowed area, with the H. zea peak occurring April 1-15 and H. virescens March 1-15.

In tests at Stoneville, alfalfa planted in the skip-rows between cotton appeared to increase the initial bollworm infestation but also furnished the beneficial insects to check the infestation before damage occurred. This was an unreplicated large scale field test and the overall bollworm population was low. This practice increased the tarnished plant bug problem reflected by the greater percentage of plant bug damaged blooms in the cotton with alfalfa in the skip rows compared with cotton with fallow skip rows.

3. Pink Bollworm. Late season treatments reduced the number of pink bollworm larave entering diapause in Arizona. Five 100-boll samples from a field where a mixture of toxaphene plus DDT was applied in September averaged 0.31 exit holes and 0.06 larvae per boll compared with 1.16 exit holes and 0.88 larvae per boll in the untreated plot.

In tests at Brownsville, Tex. insecticides were screened to develop treatments to kill moths attracted to devices containing the sex attractant. Paper hand towels were impregnated with the sex attractant and 5% solutions of dichlorvos and naled respectively and held in the laboratory for 22 days. When male pink bollworm moths were exposed to the aged residue of either dichlorvos or naled for 20 seconds, there was a 100% knockdown within 20 seconds and no recovery was noted. Celotex wafers (6x6-in) impregnated with the sex attractant and

5% solutions of dichlorvos and naled respectively were exposed to field conditions (except rain) and bioassayed periodically in the laboratory against 1-day-old male pink bollworm moths. When moths were exposed to 20 sec to a 17-day-old naled-treated and to a 14-day-old dichlorvos-treated wafer, the knowndown was 100% within 24 and 2 hrs., respectively.

4. Other Insects. At Waco, Tex. ultra low volume applications of technical malathion and Methyl Trithion, and azinphosmethyl applied as a conventional spray gave excellent initial and residual control of the cotton fleahopper. There was no difference among treatments.

At Florence, S. C. ultra low volume applications of technical Methyl Trithion at 7 fl oz/acre suppressed populations of the carmine spider mite. Methyl Trithion was more effective than malathion.

At Brownsville, Tex. studies of beneficial insect populations in 3 treated and 2 untreated fields showed that all predators and parasites were adversely affected by low volume concentrate applications of methyl parathion. Spiders appeared to be affected the least of any predators. Predator populations did not increase rapidly after treatment ceased and the plants were defoliated, but egg and larval parasite populations did show rapid increases at this time.

At Waco, Tex. heavy bollworm infestations developed in plots treated with Azodrin and Bidrin for cotton fleahopper control. Azodrin, Bidrin toxaphene plus DDT foliar applications gave significantly better cotton fleahopper control than trichlorfon. However, during the first week of July there were significantly more bollworm injured squares in the Azodrin and Bidrin treated plots than in all other treatments and the check.

Azodrin applied with the tractor-mounted brush stem-treatment applicator controlled cotton fleahoppers for 2 to 3 weeks in central Texas. In a test in Arizona, lygus bugs, Lygus hesperus, were controlled for 2 to 3 weeks on cotton 3 to 4 feet tall with Azodrin at 1 lb. per acre applied as a stem treatment.

In two field tests at Waco, Temik granules applied in the furrow at planting gave cotton fleahopper control for 8 to 10 weeks. Side-dress applications reduced the fleahopper infestation significantly below that in plots treated with 2 applications of azinphosmethyl.

Azodrin applied to the main stem of cotton plants gave control of a heavy cotton fleahopper infestation equal to that of a foliar application of toxaphene. Azodrin applied to the stem at 0.5 lb/acre or than toxaphene + DDT applied as spray.

Temik prevented hatch of tarnnished plant bug eggs in tests at College Station, Tex. when applied as a stem treatment and Azodrin caused some reduction. Most of the mortality occurred when the nymphs tried to emerge

from the egg case.

At Stoneville, Miss. phorate and disulfoton granules applied in the furrow at planting gave spider mite control for approximately 10 weeks. Mites were present in untreated plots after May 12 but infestations did not develop in treated plots until about July 20. Temik granules applied in the furrow at planting or as a side-dressing when plants began to square suppressed mites through August. The in-furrow treatment was more effective than the side-dress treatment.

In replicated small plot field tests at Florence, South Carolina seed treatments of UC-21149 and Niagara NIA-10242 were as effective against thrips and aphids on seedling cotton as the phorate and disulfoton standards. However, residual control from NIA-10242 was not equal to Temik or the standards. Loss in stands occurred with UC-21149 at 0.25 lb and Niagara NIA-10242 at 0.3 lb/acre.

At College Station, Tex. field data showed that Azodrin applied as a stem treatment to cotton plants reduced the number of bollworm predators in the fields. Laboratory studies verified this, but indicated that Chrysopa sp. may not be seriously affected.

In laboratory tests at Tucson, Ariz. 4 experimental materials were effective against third-instar beet armyworm larvae. Six were effective against adult lygus bugs. In tests against third-instar salt-marsh caterpillar larvae du Pont 1179 gave a 72-hour mortality of 80 percent when used at the rate of only 0.0625 pound per acre.

C. Biological Control.

1. Boll Weevil. Effectiveness of Mattesia grandis in boll weevil population suppression was tested in 1/16-acre field cages at the Boll Weevil Research Laboratory. The spores were applied in a formulation containing the feeding stimulant as the water extract of squares or from cottonseed oil. A dye was incorporated to mark the weevils which ingested the formulation. Results showed that the disease effectively held the adult population below that of the check, but of even greater importance was the prevention of the sharp population increase of the F_2 generation that occurred in the check. The damage to squares was reduced and the yield increased in the treated cages. The data indicated that although the treated population was about 1/2 that of the untreated, the most effective use of this disease would be in conjunction with other control measures early in the season, or during the main fruiting period of the cotton crop to provide late-season population infection.

The cost of producing Mattesia grandis was \$1.00 for 1.0972×10^8 spores while cost of producing the microsproidian was \$1.00 for 1.365×10^{10} spores. In larger production programs the cost could be reduced by perhaps one-half. Dosages of Mattesia grandis required for control in the field are too high to be competitive with chemical insecticides. However, the cost of the micro-

sporidan would be competitive with that of insecticides if it proves to be effective.

The bacterium, Serratia marcescens Bizio, was virulent to adult boll weevils in tests at Baton Rouge, La. Repeated experiments (using different concentrations of cells) indicated that the LD_{50} was 9 organisms per weevil. Mortality in weevils injected with unconcentrated cell-free filtrates from BHI broth cultures indicated that the organism produces a heat labile toxic substance.

The toxic substance of boll weevils was not destroyed when 36-hr cell-free filtrates from broth cultures of the bacterium, Serratia marcescens Bizio were lyophilized. An ammonium sulfate precipitate from the 36-hr filtrate was lyophilized and then dialyzed. The dialysis remainder produced 73 percent mortality. Preliminary investigations indicate that this preparation contains a proteolytic enzyme. This culture of S. marcescens also produced phospholipase C and phospholipases A and/or B.

A technique was developed at the Boll Weevil Research Laboratory for administering accurate doses per os of protozoan spores to the boll weevil. The technique involved suspension of spores in a thixotropic solution (hydroxyethyl cellulose) to prevent settling, and modification of procedures in the construction of micro-feeding needles.

At the Boll Weevil Research Laboratory more than 50,000 Bracon kirkpatricki adults were reared in three months on host third instar boll weevil larvae in paper-covered petri dishes. Field releases are planned and gregarious feeding behavior of larvae noted in the laboratory will be checked under natural conditions. Total life cycle in this strain was almost one day linger than for B. mellitor. As in the native species, males are produced parthenogentically. No evidence of inter-species mating was observed in several tests.

2. Bollworm. Bollworm control with polyhedral virus in field tests was variable at different locations. An Arizona in 3 large plot experiments the virus at a rate of 100 diseased larvae per acre applied by aircraft failed to give bollworm control although methyl parathion spray at 1 pound and 2.5% Azodrin dust at 40 pounds per acre gave good control. In small replicated plot tests the 400-diseased-larvae per acre rate applied with hand equipment failed to reduce a light bollworm population.

At Waco, Tex. 100 and 500 diseased larval equivalents per acre applied as sprays and 100 larval units applied as a dust gave bollworm control equal to that obtained with 2 pounds of toxaphene plus 1 pound of DDT per acre as a spray. However, control with all materials was only fair. Late in the season numerous diseased larvae were observed in all plots indicating spread of the virus through the experiment. At Tallulah, La. the 100 and 500 diseased larvae per acre rates applied as a spray and 100 diseased larvae per acre in a dust reduced the population below that of the check but the 50 diseased larvae per acre rate applied as a spray was no better than the check.

At Brownsville, Tex. 100 diseased larvae applied as a dust and 500 diseased larvae per acre as a spray gave the same control of the bollworm complex and the same increase in yield as toxaphene plus DDT. The 50 and 100 diseased larvae per acre spray treatments were less effective. At Florence, S. C. the 500-diseased-larvae equivalent per acre applied as a spray was as effective as the standard spray containing two pounds of toxaphene plus one pound of DDT per acre.

At Brownsville in laboratory and field tests, larval feeding stimulants applied with the Heliothis virus increased its effectiveness against bollworms. In field plot experiments the virus applied as a dust was more effective than a spray. Dust applications equivalent to 100 virus-diseased larvae per acre gave control that compared favorably with that obtained with the toxaphene + DDT mixture.

Mortality among Heliothis zea larvae was greater when exposed to 1, 2, or 5% boric acid solution and the nuclear polyhedrosis virus than when exposed to virus alone. One percent boric acid appeared to enhance activity as much as the higher concentrations.

Results of studies conducted under contract by the Entomology Department, Texas Agricultural Experiment Station, Texas A&M University, indicated that there was more than an additive effect on bollworm larvae mortality when the nuclear polyhedrosis and cytoplasmic viruses were used together. An added advantage for the use of the mixture would be the effectiveness of the cytoplasmic virus against other lepidopterous pests not affected by the polyhedral virus. In laboratory tests anti-feeding compound American Cyanamid 24055 combined with the polyhedral virus in a larval diet did not enhance the lethal action of the virus against the larvae but it appeared to reduce the pupation rate. In studies of virus resisdues on cotton leaves in the laboratory some virus remained on the leaves seven days after application. Infestations were too low for field tests to be conducted with the nuclear polyhedral virus against bollworms at Big Spring, Texas. However, a test was conducted in late planted cotton in October on the Weslaco Experiment Station farm in Progresso. The experiment was conducted against a mixed population of large bollworm and tobacco budworm larvae and calcium arsenate was more effective than the nuclear polyhedral virus. Previous work has shown that the virus is more effective when applied against larvae in the first or second instar.

Most important bollworm egg predators were Geocoris, Nabis, and Collops adults, and large Chrysopa larvae in laboratory feeding tests involving 30,500 bollworm eggs and 19 species of insect predators at Tucson, Ariz. Bollworm eggs glued on pieces of fresh green beans with egg albumin in groups of 10, 25, 50, and 100 eggs were confined in petri dishes with a single predator. After 24 hours the number of eggs consumed were determined.

Encarsia lutea (Masi) was the most abundant bollworm and cabbage looper egg parasite on cotton in Arizona. Eleven percent of 81 bollworm eggs and 11% of 338 cabbage looper eggs collected on 6,000 cotton plants between June 8 and August 18, 1965 were parasitized by Encarsia lutea. No bollworm eggs and only 1.2% of cabbage looper eggs were parasitized by Trichogramma sp.

Fifty-three percent of the bollworm larvae collected on cotton in central Texas were H. virescens (F.) in 1965. Of 3,466 larvae collected periodically throughout the season, 1,847 or 53% were the tobacco budworm. In 1964 only 7.4% and in 1963, 46% of the larvae collected were budworms.

Studies of effects on beneficial insects of insecticides applied on an automatic schedule begun in 1964 under contract by the Entomology Department, Mississippi Agricultural Experiment Station, were continued in 1965 in a small-plot replicated field experiment at the Delta Branch Station in Stoneville, Mississippi. The data showed that, carbaryl, endrin, azinphosmethyl, malathion and toxaphene were not consistent in their effects on populations of Nabis sp. or spiders. In most cases beneficial insects were least affected in the untreated check and most adversely affected by toxaphene. The inconsistency was probably due to the small plot size with populations being affected by treatments applied to adjoining plots. There were no significant differences in yield between treatments in 1964 and 1965. The striped lynx spider was an important predator in mid-and late season.

Under the same above contract, studies were conducted for the second year at Rolling Fork, Mississippi to study the effect on predator populations of early-season and late-season cotton insect control programs applied as needed. Nabids, big-eyed bugs and lady beetles were most abundant in early season. Orius was the dominant species and populations reached a peak in mid-June. Spider populations increased by mid-season and were dominant from mid-through late-season. All predators were reduced drastically by the late-season insecticide applications.

Preliminary results of a study conducted under contract by the Entomolgoy Department, University of California, Davis, indicated that between 12 and 15 species of spiders occur in San Joaquin cotton fields. However, final identifications are yet to be made. A species of Erigone was the most common. A species of crab spider, Misumenops sp. that frequents terminal buds of cotton plants may be the most important bollworm predator. The fauna appears to be dominated by no more than seven species. Four species of spiders are being reared in the laboratory for studies fo their biology and habits.

3. Other Insects. Studies at Brownsville, Texas showed that mass rearing of parasites for cabbage looper control is possible. Capidosoma truncatellum (Dalm), an encyrtid collected locally on cabbage looper, was reared in the laboratory to develop rearing methods. This parasite which has polyembryonic reproduction may produce around 3000 adults in a single host larvae. Cabbage looper were reared on an aritifcial media with methods developed by

Ignoffo. Parasitism ranged from low to as high as 89% in some exposed groups. The number of adult parasites developing per host larva varied greatly but the number from the higher yielding ones compared favorably with the field-collected material with up to 2565 produced from one larva.

Geocoris punctipes preyed readily on lygus nymphs. Adult G. punctipes fed on lygus numphs consumed an average of 3 second instar nymphs or 1.6 third instar nymphs per day. Salt-marsh caterpillar larvae with setae removed were better food for Geocoris punctipes than beet armyworm larvae, hamburger, liver and oxalated human blood. Geocoria punctipes required 36 days at 78° F to develop from egg to adult. G. punctipes reared at 78° F required an average of 10 days for the egg to hatch and 7, 5, 4, 4 and 6 days, respectively, in the 1st 2d, 3d, 4th and 5th instars. No pre-mating period was required for the adults but a preoviposition of about 6 days was noted. Average number of eggs laid by a female per day was 5.4.

Precise life history data was obtained at Tucson, Ariz. on two tachinids which show promise for biological control of two important cotton insect pests. Voria ruralis, which lays a microscopic egg externally on the cabbage looper, was found to vary in the period of development from egg to adult from 20.5 days at 68° F. Exorista mella, which lays a microscopic egg externally on the salt-marsh caterpillar, varied in development period from 28.5 days to 15.8 days over the same temperature range. Leschenaultea adusta which lays micro-type eggs on foliage varies in time of development from 74 days at 59° F.

D. Insect Sterility, Attractants, and Other New Approaches to Control.

1. Boll Weevil. Of 31 chemosterilants screened at the Boll Weevil Research Laboratory against boll weevils of mixed sexes by the dip method, only compound ENT 50450 gave a high degree of sterility. One dip of 15 seconds duration in a 10% concentration resulted in sterility of 100% of the eggs laid 7 days after dipping and 80% laid after 14 days. However, mortality of dipped weevils was high. Of 43 chemosterilants tested by feeding them to boll weevils in sugar water, only ENT 50451 produced a high degree of sterility. An 0.5% concentration of ENT 50451 fed in a 10% sugar water solution sterilized 86% of the eggs 7 days after feeding began. Mortality was moderate. In other tests in which 28 chemosterilants were screened by the dip technique, Olin 53331 was the only material which showed promise. Mortality of treated weevils was high by 2 weeks after treatment. ENT No. 50825 and ENT No. 51134 showed promise in feeding tests at concentrations of 10 and 25%. ENT No. 50987 was effective at concentrations at 5-7%. Some variation was noted in the effectiveness of the chemosterilants against male and female weevils.

Eleven spray applications of apholate at 1, 2, and 4 pounds per acre to cotton growing in 1.2-acre field cages reduced boll weevil populations at the Boll Weevil Research Laboratory. Suppression of the populations was observed 9-11 days after the last application. A highly significant

increase in yield of lint cotton per acre over the check was obtained at all treatment levels. HEMPA sprayed at 2 pounds per acre was ineffective in reducing boll weevil numbers. In a replicated small plot field test at Stoneville, Miss., apholate at 2 pounds per acre applied as a spray at 5-day intervals failed to reduce boll weevil and bollworm infestations below that of the check.

Study of the mode of reception of plant odors by the boll weevil at State College, Miss. indicated that the sense of smell is located in the antennal clubs. When one or both antennal clubs were removed or painted, a highly significant difference in response in ratio means (attractant: check) was noted. There was significantly greater response when only one antennal club was removed or painted over than when both clubs were removed or painted.

Studies at State College determined that boll weevil testes develop during the larval stages by mitosis. No meiotic divisions were observed prior to the pupal stage. The testes could be seen through the larval integument and sex could be determind. Ovarian growth proceeded at a slower rate than the testes, but again only mitotic figures were present during larval stages.

In tests at the Boll Weevil Research Laboratory crude cottonseed oil, regardless of extraction procedure, geographical origin, year, or age of cottonseed, caused nearly as much feeding response from the boll weevil as crude water extract of squares. Significant feeding stimulation of the boll weevil was obtained from extracts of hulls and kernels of cottonseed.

A dye incorporated in the boll weevil feeding stimulant applied to cotton plants showed promise as a technique for marking boll weevil field populations. Calco oil red N-1700 dye in the feeding stimulant from solvent-extracted cotton seed oil or in the water extract of cotton squares sprayed on presquaring cotton plants marked internally 60 to 100% of the boll weevils that fed on the plants in laboratory tests.

Laboratory bioassays demonstrated that the male boll weevil produces an airborne pheromone attractive to the female. Studies are underway to isolate and identify the sex attractant from male extracts which have shown activity.

In a large half-acre cage in Iguala, Mexico, 0.4 pound of apholate applied in cotton in a bait formulation with crude cottonseed oil as an attractant was as good or better for almost every variable measured as apholate applied to a wettable powder spray at 0.6 pound per acre.

Gene frequency experiments in closed populations at the Boll Weevil Research Laboratory showed that the gene ebony acts as if it were overdominant with respect to fitness while pearl stays in Hardy-Weinberg equilibrium. The mutants ebony and slate can be recognized at any stage of development by checking the color of the mouth parts of the immature insect or the body color of the adult.

In laboratory studies at the Boll Weevil Research Laboratory, there was little or no response of females less than 3 days old to males 4 to 6 days old and of 4- to 6-day old females to males less than 3 days old. Response reached its peak when both sexes were between 5 and 7 days old. Females responded to a single male, but response was increased significantly when the number of males was increased to 5, 10, or 25. Virgin males were more than twice as attractive to virgin females than males that had mated 1 to 6 hours before they were tested. More than 3 times as many virgin females responded to virgin males than females that had mated 1 to 6 hours before they were tested. Untreated male boll weevils attracted about twice as many virgin females as males dipped twice in a 2% apholate solution.

Research was conducted under contract by the Southern Research Institute, Birmingham, Ala., on the isolation of boll weevil feeding stimulants found in flower buds and flowers of cotton plants. An active fraction having the ultraviolet spectrum of a known porphyrin was isolated. Although it was not regarded as a pure compound, the observation led to the investigation of the possibility that one type of active ingredient in cotton squares may be a porphyrin-containing fraction or a dipydroporphyrin. Porhyrin-containing fractions with feed-stimulant activity were obtained by various methods of extraction or isolation. However, it was not possible to determine whether the porphyrins are active or whether other ingredients in the porphyrin-containing fractions were responsible for the observed feeding-stimulant activity. Previous studies appeared to impoicate the flavoniod compounds (anthocyamins, flavones, etc.) and less polar compounds auch as carotenoids, as feeding stimulants.

2. Pink Bollworm. Studies of metepa sterilized males were conducted during the 1964 and 1965 cotton growing seasons in a 1/3-acre cage divided into two equal parts-- a treated and a check section. Daily releases totaling 54,000 sterile males during the 1965 season gave 98% control of the pink bollworm population. The population was considered eradicated when no larvae were found in the treated section for three consecutive weeks. However, due to accidental moth entry, a total of 378 pink bollworm larvae were found by the end of the study in the treated section compared with 17,146 in the check section.

In studies at Brownsville pink bollworm adults were sterilized by dipping them in metepa solution. Results of tests indicated that male pink bollworm moths can be mass sterilized by dipping them in a 2.5% metepa solution. Only 1 of 3145 eggs laid by females mated with the treated males hatched. The sterile males mated as often as the normal males; however, their longevity was slightly less (13.3 and 16.4 days for sterile and normal males, respectively). A higher dosage is required to sterilize females than males.

Pink bollworm males were attracted to and taken in traps baited with 1 µg of propylure (synthetic sex attractant)/trap. This is equal to 100 female equivalents (FE) of natural lure. However, 2000 FE of propylure was required to compete with 24 FE of natural lure. Propylure was very shortlived

with 2000 FE failing to trap males by the third night. Preliminary tests indicated that an inactive extract from female moths extended the effectiveness of propylure.

Several sex-lure trap designs showed promise for pink bollworm in tests at Brownsville. A low-cost trap made from an 8-ounce paraffinated "Dixie" cup baited with the sex lure captured over 100 male moths per night. Several trap designs made from 1- and 2-quart ice cream containers also were promising. Modifications of the Steiner medfly trap with extruded plastic funnels proved to be an efficient sex-lure trap for this insect. The standard Frick fruit-fly and newer Gypsy-moth traps were less effective than several other traps tested.

E. Evaluation of Equipment For Insect Control and Detection.

1. Boll Weevil. A ground sprayer was developed for applying low volume insecticide concentrates to cotton at Florence, S. C. The sprayer consists of a Potts 3-outlet mist blower equipped with "Mini-Spin" nozzles and mounted on the rear of a high clearance Barrentine self-propelled sprayer chasis. The pressure unit consists of a 25-gallon pressure tank with pressure regulator and liquid flow control valve, a small portable air compressor driven by a gasoline line engine. In tests this season, the sprayer provided excellent applications for control of boll weevil and other insects.

A rotary disc device for applying ultra-low-volume chemicals with ground equipment was developed during the fall of 1965 at the Boll Weevil Research Laboratory. The device uses centrifugal force to disperse the insecticide. Results of field tests during the fall of 1965 indicate that boll weevil concontrol equivalent to that obtained with methyl parathion at 0.5 #/A may be expected with this device using 16 fluid ounces of a 25% azinphosmethyl emulsifiable concentrate. Results of the tests comparing this device with the mist blower machine developed at Florence indicate that the rotary disc device gives more uniform coverage on the plant and equivalent boll weevil control with azinphosmethyl.

2. Bollworms. Black light trap catches from June 22 through September 13, 1965 indicated 3 population peaks of Heliothis zea and H. virescens at Florence. The first peak occurred on June 22, the second from July 24 through August 8, and the third from August 18 through September 6. In laboratory tests at Florence, optimum sound frequency for greatest first A-cell response (acoustic sense cell) in Heliothis zea and H. virescens was in the 18-25 kc/sec range. Sound intensities of 45-50 db were sufficient to elicit sensory response at 18-25 kc/sec.

Field tests at Florence to determine the effectiveness of electronically and mechanically produced ultra sound in controlling the tympanate moth pests of cotton, Heliothis zea and H. virescens, were conducted with 21-22 kc/sec pulses and the multi-frequency output of a key jangle apparatus. Neither type of sound affected the field population sufficiently to allow measurable

effects by the sampling methods used.

3. Pink Bollworm. In studies at Brownsville a light trap baited with sex lure was very effective for trapping male pink bollworm moths. The light-sex lure trap caught 1231 males compared with 615, 235, and 206 males for the Frick trap, Johnson trap, and metal can trap, all baited with the sex lure, respectively.

4. Other Insects. Visual and mechanical methods of determining cotton fleahopper populations were compared in Central Texas. A comparison of the standard visual method of determining cotton fleahopper infestations on cotton terminal buds with the D-Vac (Model 24) vacuum sampling machine indicated little difference between the two methods for adult fleahoppers, but the visual method was superior to the vacuum machine for nymphs.

F. Varietal Evaluation For Insect Resistance.

1. Boll Weevil. In field and laboratory antibiosis studies at State College Miss. 17 non-commercial cotton lines from the Regional Collection produced weevils weighing less than 90% of those produced on a commercial check line. Previous data indicated a positive correlation between weevil weight and oviposition. The 17 lines are now available for use in developing breeding stocks containing resistance factors.

Oviposition records from laboratory weevils fed cotton squares throughout the season from two lines of cotton grown in field gave a bell shaped oviposition curve. Egg production on the lines was relatively low the first part of July, increased progressively to a peak during the first part of August, and declined steadily during the latter part of August and the first part of September. It is believed that the oviposition cycle is a reflection of the physiological condition of the cotton at various time intervals during the season. This suggests that the physiological state of cotton may be highly significant in determining ultimate population levels of certain insects in the field.

In field tests the glandless genes $gl_2gl_2gl_3gl_3$ present in Acala 4-42-77 and Rex Smoothleaf backgrounds did not affect susceptibility to the boll weevil. Infestation records throughout the season were essentially the same within the pairs of glanded and glandless Rex Smoothleaf and of glanded and glandless Acala 4-42-77. The Acala pair of lines was damaged less than the Rex Smoothleaf pair. These results are the same as last year's with these lines.

2. Other Insects. At State College, Miss. striped blister beetles and grape colaspis beetles were again pests of glandless cotton during the 1965 season, as in 1964, causing extensive leaf damage. Glanded counter-parts were not damaged.

Gossypol analysis of thirteen glandless lines indicated that some lines had gossypol in the leaves comparable with that of glanded counterparts. Other analyses revealed that (1) removal of bracts from growing squares in the field lower the amount of gossypol found in the squares of some varieties; (2) more gossypol is present in the corolla of the square than in the calyx; (3) gossypol content of leaves of glanded varieties increased directly with maturation and from early season to late season; and (4) gossypol content of squares increased from .583% on the 13th of July to .837% on the 7th day of September but a sharp decline in gossypol was noted during peak fruiting period.

In studies at Tucson, Ariz. salt-marsh caterpillar larvae fed 10 days on leaves of 2 glandless cotton varieties weighed 2 1/2 times more than those fed on the same glanded varieties. Larvae fed on terminal leaves of 4-42-77 glandless and AXTE 25 glandless had average 10-day weights of 182.2 mg and 181.9 mg respectively compared with 65.5 and 61.9 mg for the glanded varieties. Larvae fed on terminal leaves of Pima S-2 had a 10-day average weight of only 33.0 mg.

In a small field test at Waco, Tex., strain 1514 and 2 improved strains of 1514, 321 O; and 370 Op were equally resistant to cotton fleahoppers.

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AREA NO. 10. TOBACCO INSECTS

Problem. Insecticides employed to control insects that attack tobacco, particularly budworms, hornworms, flea beetles, and aphids, may cause undesirable residues on cured tobacco. These residues adhere to the leaf through commercial processing and some have been found in the mainstream of smoke from commercial cigarettes. Non-insecticidal methods for controlling insect pests of tobacco are urgently needed. Research on lures, light traps, sterilization techniques, other new approaches to control, and better utilization of predators, parasites, and diseases of tobacco insects should be intensified. Studies to find market-acceptable tobacco varieties that resist insect attack need more attention. Integrated control programs that lessen the possibility of undesirable residues should also be investigated more intensively.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing program of basic and applied research on tobacco insects to develop effective control methods that will alleviate the residue problem on the harvested leaf. The research is cooperative with State and Federal entomologists, chemists, agronomists, and agricultural engineers in the States where research is underway and with the tobacco industry. Studies are conducted at Oxford, N.C., Florence, S.C., Quincy, Fla., and at a temporary location on St. Croix, Virgin Islands, a satellite of Oxford. Contract research supported by the Department is in progress at Kentucky, North Carolina, and South Carolina Agricultural Experiment Stations, and the Virginia Polytechnic Institute. A grant for studies on tobacco insects at the Clemson Agricultural Experiment Station in South Carolina and for work on tobacco flea beetles by the University of Florida Agricultural Experiment Station at Quincy have been implemented.

The Federal scientific effort devoted to research in this area totals 6.5 professional man-years. Of this number, 1.9 is devoted to basic biology, physiology, and nutrition; 1.3 to insecticidal and cultural control; 0.3 to insecticide residue determinations; 0.9 to biological control; 1.3 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.2 to varietal evaluation for insect resistance; and 0.5 to program leadership.

In addition Federal support of research under contracts and grants provides 1.8 man-years in this area. Of this total 1.3 is devoted to basic biology, physiology, and nutrition and 0.5 to insect sterility, attractants and other new approaches to control.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 10.1 professional man-years is devoted to this area of research.

PROGRESS--USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Tobacco Hornworm. At Oxford, N.C., media-reared tobacco hornworm moths required illumination levels (ft-c) 100 times as high as tobacco-reared moths for normal activity. Electrophysiological analysis at Virginia Polytechnic Institute indicated a visual impairment which improved somewhat as the moths aged. The synthetic media contains little or no visual pigment precursors available in the host plant. The possible effect of this deficiency, if it cannot be corrected, on the effectiveness of moths that may be released in sterile release experiments has not been determined.

Female hornworms reared on synthetic media were also less particular in the choice of oviposition sites than females reared on tobacco. The percentage of eggs laid on cage surfaces by females from the laboratory culture have sometimes averaged higher than percentage found on the tobacco plants and, when tobacco plants were removed from the holding cages, large numbers of eggs were still deposited on the cage surfaces. Tobacco-reared females deposited fewer than 5% of the eggs on cage surfaces and removing the host plant terminated oviposition.

In studies with glass-bottomed wooden containers, 14 inches high with a 4x8-inch cross section filled with moist earth, 29 of 32 prepupae larvae burrowed to the container bottoms, with an average burrowing time of 39 minutes. Twenty-seven adults emerged. Soil examination indicated that the adults in some instances utilized larval entrance burrows as escape routes; however, the entrance burrows in most cases had collapsed, making it necessary for the emerging adults to push through the overlying soil. Prepupal larvae in the field burrow as far as 4-10 inches to the hard surface known as the plowsole before establishing the pupal cells. The pupal cell does not appear necessary for survival of the pupae. Some 37 adults emerged from 50 hornworm pupae distributed at 2-inch intervals to a depth of 9 inches in containers filled with dry soil. Slightly over half the pupae that did not emerge were at the 9 inch depth. Deep discing of tobacco fields after harvest, to be effective as a cultural control method, would probably be successful only if pupae were destroyed.

Tobacco hornworm moths, ranging from 12 to 96 hours old, were weighted with lead shot and allowed free flight. The performances of all age groups were similar with no evidence of flight muscle deterioration with age. Wing area averages ranged from 7.78 to 9.46 cm^2 for females and 7.19 to 8.10 cm^2 for males. Wing loading (body weight plus lead shot) expressed in grams per square centimeter of wing area was as follows: Females from .264 g/cm^2 to .308 g/cm^2, males from .251 g/cm^2 to .308 g/cm^2. Although the average wing area of females exceeded that of the males, load capacity was less and may have been influenced by a shift in the center of gravity due to oocyte production. The tests were made under conditions which were undoubtedly determintal to performance. Outside temperatures at the time of the trials

were in the middle 60's, and the trials were conducted during daylight hours (the hornworm moth is crepuscular and nocturnal in habits). The tests suggested large moths would be able to carry small radio transmitters in tracking experiments to determine flight behavior.

An automatic light intensity controller was built at Oxford, N.C., in cooperation with the Agricultural Engineering Research Division, to vary the output of incandescent or specially constructed fluorescent lamp units. Changes in light amplitude from natural sources can be simulated with the controller unit. The tobacco hornworm moth appears to respond in the same manner to natural twilight and to the "twilight" changes produced by the controller.

Also at Oxford, N.C., more than 1,000 tobacco hornworm moths were marked and released in an effort to evaluate the effectiveness of the blacklight insect traps and to aid in development of a sterile moth release program. About 8% of the released moths were recovered.

At Florence, S.C., during August and September, 100,935 nearly full-grown larvae were collected from tobacco on growers' farms. From the larvae collected, 40,260 living pupae were recovered. It was observed that when maleic hydrazide is used to control sucker growth on tobacco few hornworm larvae develop on the plants.

B. Insecticidal and Cultural Control

1. Wireworms. A method for applying insecticide granules as a row treatment was developed at Florence, S.C., in cooperation with industry. The equipment permits application at 2 different levels in the soil. Cooperative tests are being conducted with Crops Research Division in an effort to combine treatments for wireworm and nematode control.

2. Tobacco Insects. Niagara NIA-10242 was the most effective systemic insecticide tested at Florence, S.C., for the control of the tobacco flea beetle, the tobacco hornworm, and the tobacco budworm. A 10% granular formulation gave 6 weeks protection but was phytotoxic and resulted in off-flavor in the tobacco.

3. Tobacco Hornworms and Budworms. The influence of late season stalk-cutting to prevent late season breeding of the tobacco hornworm and budworm is being studied in a 113-square mile area at Florence, S.C. Growers cut 87% of their stalks and the remainder were cut by a commercial operator in 1965. Forty-eight $\frac{1}{2}$-acre plots outside of this area are being used to compare damage in 1966.

At Quincy, Fla., disulfoton granules applied to 24 plots of shade tobacco as a preplant treatment at varying dosages significantly reduced damage from the tobacco flea beetle. Two-pound treatments banded or broadcast at transplanting and then side-dressed 28 days later or a single 6-pound treatment at transplanting provided excellent protection for about 7 weeks.

C. Insecticide Residue Determinations

1. At Quincy, Fla., samples of cigar wrapper tobacco that had been treated with 4 pounds of 10% disulfoton granules per acre at transplanting were collected from different primings. All samples, check as well as treated, contained an unidentifiable phosphate compound. The quantity of this material in the check samples was approximately 10 times that found in treated plots.

Samples of green cigar wrapper tobacco that had been treated 10 times with standard insecticides (1% parathion, 10% DDT) showed 327 ppm of DDT, 6.2 ppm of DDE, and 13.1 ppm of parathion. Samples collected from another field in which no application of insecticide had been applied showed 8.4 ppm of DDT, 1.8 ppm of DDE, and no parathion. These samples were run by a commercial testing laboratory on the whole leaf with a dry base, using gas chromatography.

D. Biological Control

1. At Oxford, N.C., a culture of tachinid flies, Drino mundo, is being maintained in the laboratory with budworm larvae serving as hosts.

Approximately 3,000 tobacco budworms 15-30 mm long collected from tobacco plants between July 26 and August 18 showed 30% parasitism by Cardiochiles nigriceps at Quincy, Fla.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Tobacco Hornworms and Budworms. Evaluation of blacklight traps and stalk destruction to suppress hornworm and budworm populations was continued in a 314-square-mile area near Oxford, N.C. Populations of both species were below an economic level, making it difficult to fully evaluate the program. However, as in previous years, there was an increase in adult hornworms and eggs plus 1st instar larvae from the center of the area to the outside.

Significant increases in male hornworm catches occurred when virgin females were placed in the vicinity of blacklight traps. Mated females failed to increase the male catch and male tobacco hornworms placed near the trap failed to increase the catch of either sex. Virgin females 3 to 5 days old showed greater attraction to males than younger or older females. Iso-amyl salicylate and jimson weed blossoms used in combination with virgin females appeared to mask the attractiveness of virgin females.

At Oxford, N.C., in cooperative tests with the Agricultural Engineering Research Division, most tobacco hornworms were caught in blacklight traps from 7:00 p.m. to 2:00 a.m. and most corn earworm and cabbage loopers from 7:00 p.m. to 12:00 midnight.

Blacklight traps have been placed in operation on St. Croix, U.S. Virgin Islands, to measure their effect on isolated insect populations. Although

preliminary results on the tobacco hornworm appear encouraging, additional time is needed to fully evaluate the impact of the traps.

A rearing facility has been completed at Oxford, N.C., to produce tobacco hornworms and tobacco budworms on synthetic diet. Present equipment will permit production of 10,000 of each species weekly. A method has been developed for rearing the tobacco budworm gregariously.

2. Cabbage Looper. Preliminary studies were conducted at Quincy, Fla., to determine the effectiveness of the recently-synthesized sex lure of the female cabbage looper in conjunction with BL traps. The attractant was pipetted onto Whatman filter paper which was suspended in a Dixie cup with bottom removed and placed in the collection containers of the BL traps. The traps equipped with four 32-W circleline fluorescent BL lamps with and without the attractant were located about 1½ miles apart. The sex attractant was rotated between traps on alternate nights. In 10 nights, 171 male cabbage loopers were caught in traps baited with the sex pheromone as compared to 23 caught in unbaited traps. The data suggest that male cabbage loopers were initially repelled by the high concentration of synthetic attractant. However, more male cabbage loopers were caught each night for six consecutive nights in baited traps than in unbaited traps; thereafter, catches of male moths in baited and unbaited BL traps were about equal.

Unbaited BL traps located at distances up to 400 feet downwind from a trap containing the synthetic attractant caught more male loopers than unbaited traps upwind. The synthetic lure in this test was highly attractive for two nights but suddenly decreased the third night.

Significant progress in the production of wrapper tobacco without insecticide residues was made at Quincy, Fla. An integrated insect control program conducted on cigar wrapper tobacco reduced the number of insecticide applications by 76%. In 8 shade fields, omnidirectional light traps were placed 40-50 feet from the shade at 150-foot intervals. Disulfoton was drilled at 4 pounds per acre at transplanting time for aphid and flea beetle control; treatments with non-persistent materials such as parathion, azinphosmethyl, and the pathogen Bacillus thuringiensis were used when needed. Plants in the 8 integrated control fields showed 8% less damage from the tobacco budworm and 25% less from the cabbage looper than in fields receiving the normal insecticide treatments. The number of applications (including Bacillus thuringiensis) ranged from 2 to 7 in the 8 integrated fields compared with 7 to 14 in the shade fields receiving normal insecticide treatment.

Growers of cigar wrapper tobacco at Quincy, Fla., have entered into a 3-year insect suppression program using light traps which cover the entire Georgia-Florida shade tobacco area (400 square miles) with 3 traps per square mile. The growers realize that the traps will not eliminate insecticides completely but may reduce the amount needed. The cost to the growers per year is equal to about one insecticide application, which ranges from $5 to $8 per acre of tobacco. Although the light-trapping area has not been fully evaluated,

there are indications from surveys taken throughout the area that many growers have reduced their insecticide applications by 20 to 30 percent.

F. Evaluation of Equipment for Insect Detection and Control

1. Tobacco Hornworms and Budworms. At Oxford, N.C., tests in cooperation with the Agricultural Engineering Research Division showed increased catches of tobacco hornworm and budworm moths with increased wattage blacklight lamps. Fans above and below the baffles on the standard gravity trap increased catches of tobacco hornworms. Traps placed in wooded areas caught fewer hornworms and budworms than traps placed at the edge, and catches were greatest in open areas. Impact of blacklight traps on the ecosystem is being evaluated through a detailed analysis of all insects caught. To date more than 800 species have been recorded. A study of other animals showed that in 950 trap days only 11 tree frogs, 20 red bats, and 11 birds were present in blacklight traps.

2. Cabbage Looper. At Quincy, Fla., in cooperation with the Agricultural Engineering Research Division, light trap catches in 1965 showed that 45% of the female cabbage loopers, 59% of corn earworms, and 41% of the tobacco budworm moths were not mated when taken in light traps.

Light traps with 1, 2, or 4 15-watt blacklight lamps with fans were compared with a standard gravity trap with 1 15-W lamp. Results indicated no increase with the fan (1/100 hp); however, trap catches of small nocturnal moths, such as tobacco budworm, corn earworm, and cabbage looper increased with wattage. More Coleoptera were caught in the gravity trap (1-15W lamp) than the other traps, indicating that coleopterous insects may be repelled by higher wattages.

3. Wireworms. At Florence, S.C., 5 farms with a light trap operating and 5 similar farms without a light trap were selected to study the effect of light trapping on southern potato wireworm infestation on tobacco. Results in 1964 indicated that the total wireworm population was higher on the farms without a light trap than it was on the farms with a light trap. In 1965 there was no change in wireworm populations on farms without a light trap, but the population more than doubled on the farms with light traps. In 1964 there were more tobacco wireworms on all farms than southern potato wireworms, but by 1965 there were more southern potato wireworms than tobacco wireworms, indicating an influx of the southern potato wireworm. The results in 1965 also showed that the population was especially heavy for the first 100 feet in a linear direction from the light trap.

In 1966 the wireworm populations were about the same in fields where there was a light trap as in comparable fields where there was no light trap.

H. Varietal Evaluation for Insect Control

1. At Oxford, N.C., preliminary tests with 6 varieties of tobacco showed no difference in susceptibility to hornworm damage.

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AREA NO. 11. SUGARCANE AND SUGARBEET INSECTS

Problem. Control of insects on sugarcane and sugarbeets is essential because of destructive plant diseases spread by insects and damage caused. The use of insecticides for insect control requires special care to avoid contamination of the harvested product with undesirable residues. Safe effective methods of control are especially needed for the sugarcane borer, the sugarbeet root maggot, and the beet webworm. Sugarcane mosaic has become more important in recent years, and information on insect vectors of this disease is needed. Beet yellows and associated western yellows virus diseases of sugarbeets continue to threaten the sugarbeet industry. Emergency chemical control measures for the aphid vectors of the viruses of these diseases are urgently needed. Studies on the ecology and methods of control of the weed reservoirs of the insects that transmit the two viruses should be continued. For long-range solutions to these problems, further investigations should be undertaken to find effective parasites and predators of sugar-crop pests and to develop varieties of sugarcane and sugarbeet that are resistant to insect attack. The usefulness of destruction of alternate host plants and new approaches to insect control, such as the male sterility technique and attractants, should be investigated. Research should aim to develop control methods without objectionable features. Key insect pests that require heavy use of insecticides for their control and thereby make the natural control of other pests on the same crops difficult are special problems that should receive emphasis in the search for nonchemical methods of control.

USDA AND COOPERATIVE PROGRAM

The Department has a continuing long-range program involving basic and applied research on the insect problems of sugarcane and sugarbeet directed toward developing efficient and economical control methods. This program is cooperative with State and Federal entomologists, agronomists, and chemists in the States where research is underway and with industry. Studies on sugarcane insects are conducted at Houma, La., and Canal Point, Fla.; and on sugarbeet insects at Mesa, Ariz., Twin Falls, Idaho, and Yakima, Wash. Research on factors affecting the efficiency of Trichogramma spp. as parasites of lepidopterous pests is being conducted under a research grant with the Louisiana State University.

The Federal scientific effort devoted to research in this area totals 8.8 scientists man-years. Of this number 1.0 is devoted to basic biology, physiology, and nutrition; 2.3 to insecticidal control; 0.7 to insecticide residue determinations; 1.2 to biological control; 0.6 to insect sterility, attractants, and other new approaches to control; 0.3 to evaluation of equipment for insect detection and control; 0.8 to varietal evaluation for insect resistance; 1.3 to insect vectors of diseases; and 0.6 to program leadership.

Federal support of research in this area under grant provides for 0.3 professional man-year devoted to biological control, and 0.3 to basic biology of the beet leafhopper.

Natural enemies of the sugarcane borer in India are being studied under a PL 480 project A7-ENT-1, by the Commonwealth Institute of Biological Control, Bangalore, India. Parasites and predators found effective for borer control will be made available for use in the United States. A second PL 480 project, A7-ENT-22 has recently been initiated in India on studies of Indian Jassidae with particular reference to Circulifer and related genera and their importance as vectors of plant virus diseases.

PROGRAM OF STATE EXPERIMENT STATIONS

A total of 5.0 professional man-years is devoted to this area of research.

PROGRESS -- USDA AND COOPERATIVE PROGRAM

A. Basic Biology, Physiology, and Nutrition

1. Sugarbeet Insects. At Twin Falls, Idaho, beet leafhoppers were more numerous than for the past several years. On May 18 there were 24 leafhoppers per 100 square feet in sugarbeet fields and by June 15 populations had increased to 212 per 100 square feet. Population samples in nearby desert breeding areas also showed high leafhopper populations, and various tests indicated that approximately 4% of the leafhoppers were carrying curly top virus, the highest percentage of virus carriers recorded since 1957 in this area.

Studies in Idaho showed that the sugarbeet root maggot overwinters in the larval stage, mostly along the beet row rather than between rows. The majority overwintered in the soil at a depth of 6 to 9 inches but many were found at a depth of 3 to 6 inches. This distribution remained constant even though the ground was frozen to a depth of 12 inches in February. By June 6, 1966, in an area near Paul, Idaho, 58% of the sugarbeet plants were infested with an average of 28 eggs per plant, resulting in an average of 5 maggots per plant. Although mortality between egg and early larval instars was high, damage was severe.

In laboratory studies, potted sugarbeet plants infested with 80 maggots per plant were killed. Those infested with 40 maggots per plant were severely damaged, but no noticeable effects were detected on plants infested with 5, 10, and 20 maggots per plant.

Field studies to develop suitable attractants for sugarbeet root maggot flies showed beet juice to be more attractive than sugar solutions, beet molasses, young beet plants, or beet roots.

At Yakima, Wash., 31 species of plants, representing 8 families, were found to be hosts of both the green peach aphid and the beet western yellows virus. Many of these are perennial or autumn-sprouted annuals which serve as overwintering sources of beet western yellows.

A new leaf miner, Psilopa leucostoma Meigen, of sugarbeets was discovered in Washington in 1962. Surveys made in 1965 showed the leaf miner present on sugarbeets in Washington, Oregon, Idaho, and northern Utah. Indications are that it may become a more serious pest than the spinach leaf miner, Pegomya hyoscami.

2. Sugarcane Insects. At Houma, La., first-generation population counts in the spring of 1965 showed an estimated average of 2,705 borer-killed plants per acre - 5 times the 1965 average of 549. This was due to a relatively mild winter which resulted in 58% borer survival. The annual harvesttime survey in Louisiana in the fall of 1965 showed an average bored joint (internode) infestation of 18% compared to 11% in 1964, 12% in 1963, and 6% in 1962, and an average of 16% for the 30-year period 1935-64. Estimated crop loss was 14% compared to 8,9, and 5% for the crop years 1964, 1963, and 1962, respectively. The sugarcane borer infestation (joints bored) in Florida at time of harvest in 1965 averaged 4%. This is slightly less than in the previous year.

Plant cane in Florida was heavily attacked by lesser cornstalk borer. Armyworms and cutworms caused damage to some fields in both Florida and Louisiana. Although the European and southwestern corn borers are in northern Louisiana, they apparently have not reached the sugarcane area.

B. Insecticidal and Cultural Control

1. Sugarbeet Insects. In laboratory screening tests at Twin Falls, Idaho, against adults of the sugarbeet root maggot, beet plants were sprayed with insecticides and one day later infested with flies. Bomyl, Bay 39007, trichlorfon, diazinon, and naled gave 100% mortality in 4 hours. Bay 39007 and diazinon also produced 100% mortality of flies introduced 4 days after spraying.

Drill row treatments of granular carbophenothion, ethion, phorate, and Shell 9098 gave more effective control of the sugarbeet root maggot than topical band treatments, but in some instances were phytotoxic. None of the compounds performed as well as the heptachlor standard.

In tests at Yakima, Wash., foliar applications of granular formulations of 6 systemic insecticides satisfactorily controlled newly hatched larvae of the spinach leaf miner and an ephydrid leaf miner, P. leucostoma, before they mined the leaves of sugarbeets. All of these insecticides greatly reduced oviposition by the ephydrid leaf miner but only Temik® granules significantly reduced oviposition by the spinach leaf miner. In laboratory and field tests diazinon applied to the soil before sugarbeets were planted killed larvae of the spinach leaf miner as they mined the leaves and provided the first authentic record of systemic activity of this insecticide.

At Yakima, Wash., data supplied by cooperators showed that the sugar content of sugarbeets grown at Walla Walla, where beet yellows and beet western yellows is an annual problem, has increased since 1960 when most growers started applying systemic insecticides regularly for control of the green peach aphid, the principal carrier of the diseases.

A granular formulation of Temik® gave outstanding control of the green peach aphid on sugarbeets. Foliar applications were about as effective as preplant soil applications. Foliage of sugarbeet contained significant residues 146 days after treatment.

Sugarbeet wireworm larvae were less susceptible to aldrin soil treatments in Washington than during the 1949-51 period.

Post-planting sidedressings of granulated parathion, phorate, Stauffer N-290, and Bay 25141 applied at 3 pounds per acre reduced cullage resulting from wireworm injury 74.4 - 85.2%.

2. Sugarcane Insects. In large-scale aerial application tests in Louisiana, endrin and Guthion® were compared for sugarcane borer control at 5 different locations. Resistance to endrin was very evident at 2 locations where it gave only 15 and 7% control, respectively. At the other 3 locations there was no significant difference in the performance of the 2 insecticides, both giving about 90% control.

In a screening test on summer planted cane, Azodrin, endrin, ethion-endosulfan, and SD-8447 gave good control of the sugarcane borer with no significant difference between insecticides. Azodrin, which recently received a label for sugarcane borer control, gave better control when applied as a spray than as granules.

A comparison of automatic schedules of insecticide applications for sugarcane borer control with a schedule of applicaltions made when weekly examinations show 5% or more of the stalks with larvae feeding behind the leaf sheath showed no significant difference between the 2 methods, even though the number of applications were the same.

C. Insecticide Residue Determinations

1. Sugarbeet Insects. Significant residues of aldrin and dieldrin were found in the raw sugarbeets, dried pulp, carbonation mud, raw juice, and first carbonation juice when preplant applications of the 2 insecticides were made at 5 and 3 pounds per acre, respectively, and mixed with the soil. Significant residue of dieldrin was also found in the cossettes. Analyses were made by the Pesticide Chemicals Research Branch at Yakima, Wash.

Aerial sprays of undiluted technical (LV) and conventional dilutions of malathion (10 gal/acre), each at 12 ounces actual per acre were applied to

sugarbeets. The initial malathion residues on sugarbeet leaves from the dilute and LV sprays were 5.98 and 13.25 ppm, respectively, and decreased after 14 days to 0.05 and 3.15 ppm.

Leaves of sugarbeets grown in 2 soils, each containing 2 ppm of diazinon and Stauffer N-2790, had 0.29 ppm of diazinon and 0.048 ppm of N-2790 at harvest.

When Temik® was applied in the furrow with sugarbeet seed at planting time at rates of 1, 3, and 6 pounds per acre, only the foliage from the 3- and 6-pound treatments contained detectable residues (0.03 and 0.06 ppm of Temik®).

D. Biological Control

1. Sugarbeet Insects. In preliminary field cage tests at Yakima, Wash., foliar sprays of a nuclear polyhedrosis virus gave 90% control of the zebra caterpillar on sugarbeets.

2. Sugarcane Insects. The annual 1965 fall survey made in the area where the Cuban fly, Lixophaga diatraeae, from Trinidad, B. W. I., was released for several consecutive years through 1959, indicated a parasitization of 26%. Parasitization percentages in recent years were as follows: 35 in 1964, 18 in 1963, 0 in 1962, and 13 in each of 1961 and 1960. Recovery examinations and observations made during the 1965 harvest season indicate that the Cuban fly is spreading. Breeding stock of the Louisiana strain of the Cuban fly is now being sent to Florida for use in breeding and release of this parasite in that State. Parasitism by Trichogramma minutum in summer plant fields of sugarcane in Louisiana during September averaged 38%.

In studies conducted at Louisiana State University under grant, on ecological factors affecting Trichogramma, it was determined that there are at least 3 and possibly 4 species of Trichogramma present in the natural populations in Louisiana. Humidity had little effect on development of the parasite, but temperature had a marked effect. For example, at 63-67° F the parasite developed from egg to adult in 29-31 days, at 90° F in 7-8 days. The parasites oviposited and developed normally in viable fertilized eggs, unfertilized eggs, and fertilized eggs that had been killed by exposure to 40° F for 30 days.

Studies were continued of predaceous arthropod fauna in fields with past histories of high and fields of low sugarcane borer infestations. In pitfall traps operated during the last 2 growing seasons, 4 general groups of predaceous arthropods were collected, namely: ants, beetles, earwigs, and spiders. Ants, consisting of both native and imported fire ants may be mostly responsible for low borer infestations. The field with a history of low borer infestation yielded 106% more ants than the one with the highest borer infestation. There were also 90% more spiders in the lightly infested

field, indicating that these arthropods could be important in the borer-predator complex.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Sugarbeet Insects. Deep drainage ditches in the Yakima Valley in Washington provided protection during the winter for summer forms of the green peach aphid and their weed hosts, many of which are also overwintering sources of the destructive beet western yellows virus. Truck-mounted propane burners were used to destroy the weeds along 42 miles of ditches within a 22-square mile test area in March of 1965 and 1966. In 1965 the aphid populations were greatly reduced on approximately 2,000 acres of sugarbeets within the control area and 74% fewer beets showed symptoms of the disease than in a similar area outside of the control area. Results through June 1966 showed 67% fewer aphids present on sugarbeets within the control area than in the outside area.

2. Sugarcane Borer. The artificial diet developed by Louisiana State University for rearing the sugarcane borer was improved by the addition of extra protein - Brewer's yeast, hydrolyzates of yeast, corn, casein, and soya. The diet containing soya hydrolyzate was the best diet, being equally acceptable to first as well as later instar larvae. Diets with Brewer's yeast were readily acceptable to later instar but not first instar larvae. Formaldehyde, Tegosept, and potassium sorbate were used to prevent bacterial contamination.

Preliminary data indicated that the total area of sensory surface of the male antennal flagellum was important for sensing the female pheromone. When antennae were removed, male moths had difficulties in making sexual contact with females.

Sex attractants of the cabbage looper, pink bollworm, and gypsy moth, supplied by the Pesticide Chemicals Research Branch, were tested on the sugarcane borer in the laboratory. There was no response.

Two 2-watt argon glow lamps, shown to be successful in attracting pink bollworm moths were field tested against the sugarcane borer in 1965. From May 18 to September 9 catches averaged less than 2 moths per trap per night although thousands of moths were in the field during the period.

F. Varietal Evaluation for Insect Resistance

1. Sugarcane Insects. Of 428 sugarcane varieties tested at Houma, La., in hand infested plots in 1965, 25% had a lower percentage of joints bored, and 37% produced more sugar per acre than standard variety C.P. 36-105.

Thirty-seven varieties of sugarcane consisting of one control variety, one new commercial variety, and 34 unreleased varieties were field tested under 2 levels of borer infestation in 1965 to obtain information on their relative tolerance. Varieties C.P. 58-48, L. 61-40, L. 6167, and C.P. 61-90

showed a loss of less than 7 pounds of sugar per acre for each 1% joints bored in both 1964 and 1965. The average loss for all 37 varieties in the test was 31 pounds in each of these two years. The greatest loss was shown by varieties L. 60-25, C.P. 61-41, L. 60-9, and C.P. 58-51. Their average loss for the 2 years ranges from 82 to 60 pounds for each unit of infestation.

Five new borer resistant parent varieties were recommended to sugarcane breeders in 1965 for use in their breeding program. The 5 varieties are: L. 61-40, L. 61-67, C.P. 61-90, C.P. 65-433, and H-58-7-150.

The borer infestation for 26 lines of corn and 3 of sorghum field tested at Houma in 1965 showed the sorghums to be generally more resistant than the corn. For the corn lines, infestations ranged from a high of 6.6 to a low of 2.0 borers per stalk. Lines MP 313E, L 501, SC 229MH, and 382(11)1-3 x 375(7)1-3 appear to be resistant when compared to the higher infestations in 409, 166, 304(11)1-2 X 471-U6, and 20 x 409. Of the 3 sorghum varieties tested Lindsey 77F had a lower infestation than either ODC 19 or Green M.

G. Insect Vectors of Diseases

1. Sugarbeet Insects. At Yakima, Wash., heavy applications of nitrogen fertilizer to sugarbeets resulted in masking symptoms of beet western yellows which is transmitted by the green peach aphid. In 1965 twice as many plants showed disease symptoms in untreated plots as in plots treated before planting time with 300 pounds of nitrogen per acre.

2. Sugarcane Insects. Tests were conducted at Houma, La., to determine if the spread of sugarcane mosaic could be reduced by controlling the insect vectors of the disease. In the first, toxaphene-DDT, General Chemical GC-6506, TDE, and diazinon applied with a spreader-sticker gave vector controls ranging from 67 to 100% with no disease reductions in any treatment. In the second, TDE and diazinon applied with and without spreader-sticker gave vector controls ranging from 38 to 100%. TDE with and without spreader-sticker reduced mosaic infection by 33% and diazinon alone showed a 13% reduction. All chemicals gave a 100% control of the rusty plum aphid, Hysteroneura setariae, one of 4 recorded vectors and the only species for which sugarcane is a natural host. No phytotoxicity was encountered with any of the insecticides.

Vector-virus relationship studies with the rusty plum aphid show that (a) the insect became viruliferous within 5 minutes after being placed on mosaic-infected plants; (b) viruliferous insects transmitted mosaic within 5 minutes after being placed on healthy sugarcane plants; (c) the aphid apparently lost the ability to transmit mosaic within 1 hour after being removed from diseased plants; (d) the rusty plum aphid was completely controlled by 6 insecticides in the field. However, controlling the vector had no apparent effect on mosaic spread.

Populations of 3 vectors of sugarcane mosaic virus, the corn leaf aphid, rusty plum aphid, and the ambrosia aphid, were lower than in 1964 in Louisiana.

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AREA NO. 12. ORNAMENTAL SHRUB, FLOWER, AND TURF INSECTS

Problem. Ornamental shrubs, flowers, and turf are damaged by the feeding of a variety of insects and mites and by diseases spread by insects. Effective and safer control measures are needed for many of these pests. Knowledge of the distribution of insect pests of these plants and information on their biology and behavior are required to provide a sound basis for the development of practical, effective, and safe control measures. Insecticidal and cultural methods of control that will not affect adversely the growing plants or natural enemies of the pests or result in objectionable insecticidal residues are needed. The nature and cause of strains of insects and mites resistant to insecticides and means of overcoming or preventing resistance require continuing investigation. The role and use of biological control agents should be more fully explored and efforts made to integrate biological, insecticidal, and cultural control methods. Use of controlled light and other physical factors as possible means of controlling greenhouse pests should be given more attention. Increased emphasis should be placed on attractants, chemosterilants, and growth or reproduction-affecting substances.

USDA AND COOPERATIVE PROGRAM

The Department has a long-range program of basic and applied research on insect and mite pests of ornamental shrubs and flowers at Beltsville, Md., Farmingdale, N.Y., and Sumner, Wash., in cooperation with State Experiment Stations of Maryland, New York, Oregon, and Washington, and with the Crops Research Division; and on turf insects at Moorestown, N.J., and Geneva, N.Y., in cooperation with the State Experiment Stations of New Jersey, New York, and Michigan, and the Northern Utilization Research and Development, Plant Pest Control, and Agricultural Engineering Research Divisions of ARS. Research on turf insects is also conducted under grant with the University of Florida.

The Federal scientific effort devoted to research in this area totals 8.3 scientist man-years. Of this 1.0 man-years are devoted to basic biology and and nutrition; 2.6 to insecticidal control; 0.6 to insecticide residue determination; 1.1 to biological control; 2.2 to insect sterility, attractants, and other new approaches to control; 0.1 to evaluation of equipment for insect detection and control; 0.1 to varietal evaluation for insect resistance; 0.1 to insect vectors of diseases; and 0.5 to program leadership.

In addition Federal support of research in this area under grant provides for 0.4 professional man-year devoted to basic biology and 0.2 to insect attractants.

A PL 480 grant to Poland provides for studies on susceptibility of red spider mites to acaricides and on the cholinesterase in red spiders as influenced by acaricides.

PROGRAM OF STATE EXPERIMENT STATIONS

The State stations are devoting 17.7 professional man-years to the research in this area.

PROGRESS--USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Japanese Beetle. A diet was developed for feeding adult Japanese beetles at Moorestown, N.J. Laboratory reared females fed this diet laid an average of 16 eggs per female as compared to 2 eggs per female fed apple slices.

Results of studies on developmental time of various immature stages of Japanese beetle showed that approximately 7.8, 12.2, and 6.9 days were required respectively for prepupal, pupal, and adult pre-emergence periods at 77° F as compared to 4.7, 7.5, and 4.4 days in each case at 84.2° F.

Also at Moorestown, N.J., a number of commercial lacquers, paints, and fluorescent materials were evaluated for use in marking Japanese beetle adults for use in sterile insect release and migration studies. A V & S Gloss Spray Enamel #1342, canary yellow, was found to be the most satisfactory of marking materials tested. There was no apparent toxicity to the beetles.

Fifty male, marked Japanese beetles were placed with 25 female beetles for sexual response to the female. Forty-six extruded their aedeagus within 90 minutes. The following day the 50 marked beetles were released in a constant temperature-humidity room held at 86° F and 75% relative humidity. Forty-seven flew within 20 minutes.

2. Cuban May Beetle. Surveys conducted in 1965 at Miami by the University of Florida under a grant showed that 210 square miles were infested with Cuban May beetle in Dade County as compared to 10 square miles in 1959. Cuban May beetle adults were noted to feed on numerous shrubs and trees, especially Trema sp., West Indies mahogany, royal poinciana, shaving brush tree (Pachira sp.), sapodilla, roseapple, and Philodendron, resulting in severe defoliation.

Larval surveys revealed that the heaviest infestations were in St. Augustine grass, with as many as 16 larvae per square foot. In waste areas under Trema sp., as many as 25 larvae per square foot were found. Most larvae occurred in the top 3" of soil. There has been no evidence of injury to plants from larvae feeding.

Mating of the Cuban May beetle occurs immediately after flight begins in the evening and usually lasts 15 to 20 minutes, although a few were observed to continue as long as 40 minutes. The adults fly to food plants or move to higher foliage in the trees after mating at dusk. They feed throughout the

night and do not leave until dawn. Beetles do not drop to the ground as previously believed but take flight and appear to fly toward dark, bushy areas.

Attempts to rear larvae of the Cuban May beetle in hollow drain tiles sunk into the ground were unsuccessful. The beetles oviposited in the soil and eggs hatched but no larvae developed. Artificial diets attempted have not been successful except one larva survived 6 weeks on Shorey's diet.

Adult Cuban May beetles marked with fluorescent paints lived as long as unmarked beetles. Applications of clear lacquer over the paint caused 50% mortality within 24 hours. Released marked beetles were recaptured up to 1300 feet from point of release. A few marked beetles were more than 1 month old when recaptured.

3. Two-spotted Spider Mite. In Poland (PL 480 project E21-ENT-5) efforts were made to develop a highly resistant strain of Tetranychus urticae by repeated selection pressure with malathion on 8 colonies of mites from various locations. However, resistance was not increased beyond 2.5-fold levels. A mite collection from greenhouse roses where acaricides had been applied gave similar negative results. These findings agree with those of studies in the United States where resistance appeared in only a few greenhouses of the thousands being treated intensively with the newer insecticides.

B. Insecticidal and Cultural Control

1. Japanese Beetle Grubs. Soil in field plots in pasture located near Sparta, N.C., were treated with different dosages of diazinon and carbaryl in July 1965. Adults had laid eggs but were still active and some had hatched to first-instar larvae. Late third-instar grubs from 1964 that had not yet transformed to pupae were also present. In September 1965, the reductions in grub population in the diazinon plots were about 38, 89, and 97% at 1.6, 4, and 6.7 lb/acre respectively, and 85 and 91% in the carbaryl plots at 9 and 18 lb/acre respectively. Populations in untreated plots averaged 15 larvae per square foot.

2. Two-spotted Spider Mite. At Farmingdale, N.Y., Temik on corn cob granules applied to the soil surface in greenhouse rose beds at 12 pounds actual toxicant per acre killed two-spotted spider mites. After 5 weeks no living mites were found on treated plants, but heavy populations had built up on untreated plants. Retention of toxicity in new rose foliage for at least 35 days was shown by transfer of mites to treated plants and resulting mortalities of 48% on young expanding leaves and 97% on older leaves.

At Beltsville, Md., 7 weekly applications of oxydemetonmethyl in sprays or dichlorvos in aerosol caused no injury to leaves or bracts of latex-free poinsettias and reduced resistant mites to noninjurious levels. Diazinon and dimethoate caused no foliage injury, but diazinon caused fading of red color in bracts. Dimethoate caused marginal necrosis as well as bract fading. Binapacryl was again superior for control of resistant two-spotted

spider mites and caused no visible leaf injury but caused slight fading of bracts. Two or three binapacryl sprays before bract development would be acceptable. Malathion WP or EC at low dosages caused no injury to foliage or bracts, but at higher dosages bract damage was severe.

3. Pritchard Mealybug. Soil drenches containing diazinon, malathion, and zectran controlled Pritchard mealybugs on African violets at Beltsville, Md.

4. Tulip Bulb Aphid. At Sumner, Wash., phorate, disulfoton, and Bay 25141 preplant furrow treatments in September 1964 at the rate of 2 pounds actual/acre gave 100, 99, and 98% control, respectively when bulbs harvested in July 1965, were artificially infested with tulip bulb aphids. In October 1965, tulip bulb aphid mortality after infestation of harvested bulbs was as follows: Phorate-15%, disulfoton-88%, and Bay 25141-22%.

Tulip bulb aphids were controlled in excess of 90 days on dormant iris bulbs dipped for 5 minutes in either benzene hexachloride or endosulfan at a 1-400 dilution. Cygon and oxydemetonmethyl failed to control the aphid at the end of 30 days after a 15-min dormant bulb dip. None of the treatments were phytotoxic or prevented aphids from feeding on the foliage after the bulbs were forced.

On iris bulbs that had broken dormancy and had growing tips of 1 inch in length, a 5-min dip in Cygon and oxydemetonmethyl gave complete aphid control throughout the forcing period. BHC and endosulfan failed to control the aphid after new foliage was produced.

5. Orange Tortrix Larvae. At Sumner, Wash., detached geranium leaves were dipped in either Zectran or Thuricide 90T and placed in petri dishes. Fourth instar orange tortrix larvae placed on the leaves 24 hours later left the Zectran treated leaves in 2 hours or less and all died within 24 hours without any feeding damage. The larvae placed on Thuricide 90T treated leaves did not feed for about 24 hours. At the end of 1 week, only about 30% of the larvae were dead on the Thuricide-treated leaves and larval feeding was extensive. Zectran applied at this rate showed no phytotoxic effect on 15 varieties of rhododendrons, 4 varieties of fuchsias, 7 varieties of azaleas, and on holly, huckleberry, and gloxinias.

6. European Chafer. At Geneva, N.Y., malathion LV (low volume) concentrate at 1.4 oz actual toxicant per medium size tree gave 86.5% control of European chafer adults the first night. At 8.2 oz this material gave 86.9% and 77.2% control 4 and 10 nights, respectively, after application.

Laboratory tests at Geneva, N.Y., showed that the initial effectiveness of aldrin and dieldrin against third instar chafer larvae was suppressed by muck soil and that the degree of suppression diminished with increased exposure.

7. Cuban May Beetle. Under a grant at the University of Florida, Miami, aldrin and heptachlor have shown the greatest reduction in number of adults emerging each season from soil-treated plots as compared to untreated plots.

In preliminary screening tests, 100% mortality was obtained in 24 and 48 hours when Cuban May beetles were exposed to foliage sprayed with diazinon at 0.25 or 0.50 lb/100 gal and in 48 hours when 1 lb/100 gal of malathion, carbaryl, or endosulfan was used. DDT residues did not give satisfactory control.

C. Insect Residue Determinations

1. European Chafer. At Geneva, N.Y., drosophila bioassays of soil residues from field plots treated with granular parathion, diazinon, carbaryl, and Bay 39007 at 20 pounds, or phorate and Zytron at 10 pounds per acre disced to a 3" depth indicated that the insecticide treatments were inadequate for seasonal control (12-14 weeks) of first instar European chafers.

Drosophila bioassays also indicated that activated charcoal applied at rates up to 320 times the amount of dieldrin present in field plots failed to render the soil nontoxic.

D. Biological Control

1. Japanese Beetle. Milky disease in granular formulations were applied by airplane at the rate of 51 pounds per acre to two 10-acre plots in Lumpkin County, Ga., during September 1965. Formulations applied to one plot contained 100,000 milky disease spore per gram and to the second contained 200,000. Examinations of soil samples in May 1966 provided inconclusive data on effectiveness of the treatment.

Soil samples from field plots near Sparta, N.C., treated in December 1964, with milky disease were collected for bioassay on May 12, 1966. Results showed 24, 76, 48, and 80% diseased larvae in plots treated with 2, 20, 200, and 2,000 pounds per acre respectively, of a granular formulation containing 1,000 spores/g. Percentages of diseased larvae were 24, 52, 56, 80, respectively, where 2, 20, 200, or 2,000 pounds per acre of a dust formulation containing 1,000 spores/g had been applied.

Also, at Moorestown, N.J., a Bacillus sp. has been cultured in the laboratory on several types of media, including brain-heart infusion agar, nutrient agar, and yeast dextrose agar. Exposure of Japanese beetle grubs to these in vitro spores resulted in 75 to 90% infection.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Japanese Beetle. At Moorestown, N.J., male Japanese beetles were sterilized by short interval contacts with surfaces sprayed with tepa. Female beetles copulate more than once. Females copulating first with sterile

males and then with fertile males deposit fertile eggs. However, if a sterile male mates with a female previously mated with a fertile male, ova are infertile. The mean dosage of tepa needed to sterilize males is .0625%. This dosage only sterilized about 34% of the females. A 1% tepa solution is needed to sterilize 100% of the females.

At Moorestown, N.J., 19 males were treated with 10 µg tepa (a 90% sterilizing dosage) and 19 untreated were kept as controls. Virgin females equal in numbers to the surviving males were placed with males at intervals of 4 to 5 days, removed after copulation, and fertility of the ova determined. No progression toward increased fertility with time extension occurred. Sterility remained at 90% except in the final group of females where sterility dropped and then only 1 of 5 ova was fertile.

At Moorestown, N.J., 31 different aromatics were screened in an all glass, closed-type olfactometer for attractancy to laboratory reared virgin female Japanese beetles starved for 12 hours before exposure. The more promising of these attractants were tetra hydro mugyl acetate, citronellol, citronellyl methyl acetal and fructone.

A large-scale bait trap experiment on Nantucket Island utilizing 2,332 Ellisco Japanese beetle traps baited with anethole-eugenol (9:1) resulted in the capture of 22,691 Japanese beetles, an average of 10 per trap. Traps in low land areas that retained moisture or in irrigated lawn areas averaged 31 and 23 beetles per trap, respectively. Beetles first emerged on the island July 4 and continued their activity through September 30, a period of 89 days. Peak captures occurred August 15 to 31.

In conjunction with this experiment, a number of candidate bait combinations were tested. Phenyl ethyl butyrate-eugenol 9:1, technical geraniol-eugenol 9:1 baits were more effective attractants than the standard anethole-eugenol bait. Caproic acid-eugenol 9:1, caproic acid alone, phenyl ethyl butyrate alone or with caproic acid 9:1 parts, phenyl ethyl butyrate-caproic acid-eugenol, 1:8:1, and a 10% fermenting aqueous solution of dark brown sugar-Tween 20,9:1 were less effective than the standard bait.

Bumblebees were attracted to the Japanese beetle traps during 1965 in large numbers, and 1,823 standard traps caught 18,183 bumblebees during the season and 1,166 were caught in traps with special baits. Most of the bumblebees were workers. White traps were the most attractive to bumblebees, yellow next, and green least attractive. Similar results were obtained in unbaited, colored traps.

Other pollinating insects taken in traps in small numbers included Apis mellifera (Honeybee), Magachille addenda, and Halictus and Lasioglossum sp.

Male and female Japanese beetles responded to cold trap collected sex odors at Moorestown, N.J. Males extended their antennae and assumed a copulatory position. Between 62 and 85% of the males were attracted to the female

extract and moved to it passing up the male extract. Females did not respond to the female extract but extended their antennae, assumed a copulating position, and moved toward the male extract when they were exposed to it.

2. Aphids. At Farmingdale, N.Y., from 96 to 99% aphid repellency was obtained by aluminum foil, smooth or embossed aluminum on wet strength paper, aluminum printed paper 2-inch foil pieces applied to black asphalt to give 80% aluminum coverage, and aluminum dust on asphalt. Titanium white in four mil polyethylene repelled 97% of flying aphids but in tests over soil did not prevent germination and growth of weeds. Aluminized plastic ribbon suspended 1 foot above ground level was not effective.

Yellow water-pan traps, placed on a pole at 3-foot levels from the ground up to 15 feet showed that 72% of the aphids were trapped at ground level and that progressively fewer aphids were trapped at elevations up to 12 feet. On poles over 4-foot and 16-foot squares of aluminum the aphids trapped at ground level were reduced 92 and 98% respectively. A few more aphids were captured at the 3-and 6-foot levels, but at all heights over aluminum the catches were lower than on unmulched check plots.

3. Orange Tortrix. In field cage studies at Sumner, Wash., a trap containing 10 one-day-old virgin female orange tortrix moths caught 82% of the total male population released in the cage at the end of 5 days' time. The greatest single day's catch occurred on the second day when 55% was trapped. The effectiveness of the trap dropped rapidly after the second day.

In laboratory cage tests, traps containing 1, 5, 10, or 25 live one-day-old virgin female orange tortrix moths caught 54%, 72%, 27%, and 28%, respectively, of the male moths released in the cage. Overcrowding of females in the trap apparently causes a loss in the effectiveness of the trap.

4. European Chafer. At Geneva, N.Y., blue-green lamps, infrared radiation, and silhouetted black light were found inferior to conventional black light as lures for European chafer adults. Baiting black light traps with 15 to 50 virgin or non-virgin male or female European chafer adults did not increase attractiveness as compared to non-baited black light traps.

5. Cuban May Beetle. In studies under a grant at the University of Florida, Miami, 50,000 Cuban May beetles were caught in a 30W black light trap in 7 nights. Circular-22W, semi-directional light traps averaged 10,000 beetles per week.

F. Evaluation of Equipment for Insect Detection and Control

1. Japanese Beetle. Low volume malathion sprays applied by helicopter at 8 oz/acre on 400 acres in the Tennessee valley killed 90 to 95% of the adult beetles present at the time of application. Eight applications at 5 to 7-day intervals during the period of adult activity suppressed populations

throughout the emergence period. Collections of insects and observations indicated that the sprays killed many beneficial insects in the treated area. Honey bees in unprotected hives were destroyed after 4 applications, but beehives protected by a plastic shade remained active.

At Moorestown, N.J., a Japanese beetle shipping container was developed from a 1-gallon ice-cream carton. The container can be taken to the field and collected beetles (approximately 3,000) placed directly into the carton.

Approximately 50,000 beetles were shipped from Georgia and North Carolina during June. Mortality was less than 1%.

G. Insect Control Treatments for Commodities Regulated by Plant Quarantine

1. European Chafer. At Geneva, N.Y., methyl bromide fumigation at $\frac{1}{2}$ pound per 100 square feet applied under plastic film to recently cultivated field plots gave 100% control of third instar European chafer larvae 6 inches below the surface. Air temperature under the film at application was 85° F. Mortalities occurred within 24 hours.

H. Varietal Evaluation for Insect Control

At Beltsville, Md., infestations of vegetable leaf miners in 17 varieties of chrysanthemums varied from complete immunity to high susceptibility. Hatching larvae varied from 3 in one variety (Princess Anne) to 139 in another (Blue Chip) when plants of uniform size were exposed to ovipositing adults. Survival of larvae in Princess Anne was 0% and in Indian White it was 94.5%. Development of larvae in resistant varieties of chrysanthemum was slower than in susceptible varieties, 10.8 vs. 9.7 days. The average developmental period for all chrysanthemum varieties was 10.1 days compared to 6.2 days in lima bean.

I. Insect Vectors of Diseases

At Farmingdale, N.Y., mulches of 6 reflective test materials varied in their repelling action to alate aphids and in reduction of CMV infection in gladiolus. The mulches in descending order of efficiency were: smooth aluminum on paper, embossed aluminum on paper, white plastic, aluminum powder on asphalt, black plastic, and aluminized plastic. At first the aluminized plastic was equal in repellency to aluminum on paper but lost its repellency as the aluminum loosened from the plastic.

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